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Volume I

MINIMUM FLYING QUALITIES

Volume I: Piloted Simulation Evaluation of Multiple Axis Flying Qualities

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The project was initiated to explore the modern nature of minimum flying qualities in the presence of modern aircraft and multi-redundant flight control system technology. It had several phases, including: 1) an intensive effort to develop and/or elaborate existing pilot modeling analysis techniques to apply to situations associated with minimum flying qualities, divided attention pilot operations, and multi-axis control tasks, 2) preliminary analyses and associated fixed base simulations to expand the meager multi-axis data base and to serve as pilot studies for more extensive simulations on the Air Force's Large Amplitude Multimode Aerospace Research Simulator. 3) an extensive simulation program on LAMARS to investigate minimum flying qualities and related situations, and 4) analysis and interpretation of both the early and LAMARS simulation efforts in the context of the pilot modeling advances. The project documentation appears in three volumes. Volume I reports on the results of 2) through 4) above. Volume II is a stand-alone monograph on pilot modeling, including procedures for estimating pilot workload as "measured" by pilot ratings Volume III is a stand-alone monograph which presents a detailed implementation of a much expanded version of the human optimal control model on Program CC.

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FOREWORD

The work reported herein was performed during the period from October 1985 to May 1989 under Contract F33615-85-C-3610 from the Air Force Wright Research and Development Center (formerly Air Force Wright Aeronautical Laboratories), Air Force Systems Command. Mr. Thomas Gentry of WRDC was the original Contract Technical Monitor; this duty was later transferred to Captain Mark Detroit (USAF). Mr. Duane McRuer was the STI Technical Director. The STI Project Engineers were Messrs. Roger H. Hoh and David G. Mitchell.

The project was initiated to explore the modern nature of minimum flying qualities in the presence of modern aircraft and multi-redundant flight control system technology. It had several phases, including: 1) an intensive effort to develop and/or elaborate existing pilot modeling analysis techniques to apply to situations associated with minimum flying qualities, divided attention pilot operations, and multi-axis control tasks; 2) preliminary analyses and associated fixed base simulations to expand the meager multi-axis data base and to serve as pilot studies for more extensive simulations on the LAMARS; 3) an extensive simulation program on LAMARS to investigate minimum flying qualities and related situations; and 4) analysis and interpretation of both the early and LAMARS simulation efforts in the context of the pilot modeling advances. The project documentation appears in three volumes. This Volume presents the results from 2) through 4) above. Volume II is a stand-alone monograph on pilot modeling, including procedures for estimating pilot workload as "measured" by pilot ratings. Volume III is a stand-alone monograph which presents a detailed implementation of a much expanded version of the human optimal control model on Program CC. This permits detailed analyses using algorithmic pilot models on personal computers with commercially available controls analysis software. It is expected to make pilot-vehicle analyses by flying qualities engineers possible on a more routine basis.

The authors wish to acknowledge the contributions of a number of individuals at both STI and WRDC. The sincere efforts of all of the pilots, especially during the sometimes tedious compensatory tracking

evaluations, resulted in a high-quality end product. The subject pilots were Messrs. Roger H. Hoh, Donald E. Johnston, and David G. Mitchell of STI; Majors John Barry and Tom Schipper and Captain Edward Wilson of the USAF; and Mr. Brian Van Vliet of WRDC. The following individuals at STI gave valuable technical assistance and insights throughout the project: Messrs. Irving L. Ashkenas and Henry R. Jex, during simulation planning; Messrs. Jeffrey R. Hogue and Raymond E. Magdaleno and Dr. James C. Smith, with hardware implementation and software support for the STI simulation; Mr. David H. Klyde, with data analysis, pilot modeling, and report preparation; and Ms. Bess Shields, Ms. Dorie Taylor, and Mr. Charles Reaber of the publications staff, with report typing and graphics.

Special recognition and appreciation are due to Messrs. Tom Jacobs and Brian Stadler of WRDC (FIGD), for their diligence in the preparation and conduct of the piloted simulation on the Air Force's LAMARS facility; and to Captain Mark Detroit of WRDC (FIGC), for his valuable assistance during the simulations, and for his persistence in searching for evaluation pilots.

SECTION I

INTRODUCTION

A. BACKGROUND

With aircraft missions in which high cognitive and managerial requirements are placed on the pilot, or where failures may significantly degrade one or more aircraft control axes, the pilot must divide his attention among several axes or, more generally, between control and other tasks. The combined effects of degraded response and divided attention can result in overall pilot-system performance that are far worse than would be expected as a result of any single degrading feature. All these factors unite to complicate the nature of minimum flying qualities.

1. Nature of the Minimum Flying Qualities Problem -- Now and in the Future

As the first step in addressing the issue of minimum flying qualities, we address the nature of the problem as it now exists, and as it is likely to exist in the future.

At present and in the past, minimum flying qualities issues have been limited primarily to:

- Essentially conventional airplanes, incorporating control and stability augmentation systems (CSAS), with pilot control actions using essentially conventional effectors (e.g., Table 1, Items A and B).

- Nearly <u>full pilot attention</u> available for <u>control</u> actions during conditions involving minimum flying qualities.

- Underlying available minimum flying qualities data that mostly apply strictly to single axis control, usually in the presence of good flying qualities in other axes.

- Handling qualities criteria oriented primarily towards defining the boundary between Levels 1 and 2 that may not be appropriate for the definition of the boundaries between Levels 2 and 3 without modification.

TABLE 1. SUMMARY OF MINIMUM FLYING QUALITIES SITUATIONS

SITUATION	NATURE OF MINIMUMS
MINIMUM FLYING QUALITIES SITUATIONS AKIN TO PAST USAGE	
(A) Conventional Aircraft with CSAS plus Mechanical Controls	1. Bare aircraft if CSAS single thread (e.g., failed CSAS) 2. Degraded flying qualities (FQ) (nominally Level 2) with failures in multiredundant CSAS 3. Battle damage degradations: manipulator restraints, effectors, etc.
(B) Multiple Redundant, Fail Operate, Triplex (with backup)	1. Effective dynamics with backup 2. Degraded FQ for extreme conditions with FCS failures 3. Battle damage of effectors (effective dynamics of reconfigured FCS)
NEW MINIMUM FLYING QUALITIES SITUATIONS	
(C) Multiple Redundant, Dual Fail Operate, Quadruplex (no backup)	1. Degraded FQ for extreme conditions with FCS failures; tend to be associated with power sources 2. Battle damage of effectors (effective dynamics of reconfigured FCS)
(D) Multiple Redundant FCS with Dual or Single Flight-Critical Display Elements	1. Display degradations leading to excessive divided attention (possible shift in Levels 2,3 boundary)
(E) Multiple Redundant FCS with Integrated Flight/ Propulsion Controls	1. Partial failures/damage in propulsion effector(s)
(F) Multiple Redundant FCS with Integrated Flight/ Propulsion Controls in Developmental Status Prior to 1st Flight in New Flight Regime	1. Aircraft/propulsion dynamics subject to unknown variations uncertainties 2. Minimum FQ (and effective vehicle dynamics) specified in terms of phase/gain margins (as for Shuttle)

For certain existing and future missions the problem is not so simple. For instance, considering safety of flight as paramount (as distinguished from mission completion or diversion to a new mission):

- For some mission phases the pilot is not always able to devote nearly full attention to control operations under minimum flying qualities conditions (which may include primary display degradations, Table 1, Item D).

- With modern multiple redundant fail-operational flight control systems (FCS) combined with aircraft-alone characteristics designed to optimize "performance" (as defined by classical performance qualities, new maneuvering performance metrics, observability, etc.) the sources of flying qualities degradations shift from primarily aircraft parameters to a more comprehensive inclusion of control system partial failure/degradation characteristics (Table 1, Item C).

- On future aircraft the partial or total loss of conventional primary control effectors and/or other elements of the flight control system will be offset for flight safety purposes by reconfiguration of controls, possibly including secondary effectors and certainly including modifications of piloting technique (Table 1, Items E and F).

2. Implications of Future Trends in Mission Tasks, Degradation in Control System Dynamics, and Flight Safety on Minimum Flying Qualities Requirements

a. Divided Attention Pilot Operations

A critical minimum flying qualities problem is associated with mission tasks that do not permit full-attention pilot control activities. As an example, consider flight control system degradations that occur during a very low altitude ingress/egress flight over heavily defended territory. Although the mission might be modified or even aborted, the pilot's cognitive and other managerial task loads are still very high since he must maintain very low level flight or suffer grievous harm. Consequently, the minimum flying qualities requirements for this mission phase must be based upon a much reduced level of piloted control of the aircraft.

b. <u>Key Parameters and Factors Associated with Flying Qualities of Highly-Augmented Aircraft Flight Control Systems</u>

Figure 1 shows the elements of the "Equivalent Vehicle" that the pilot is expected to control. In principle, failures or degradations of any of these elements that result in a situation involving flight safety are sources of interest in the establishment of minimum flying quality requirements at the Level 2 boundary.

Figure 2 exposes two of the key features of highly-augmented aircraft flying qualities --- the primary importance of <u>control system</u> and aircraft transfer function numerator parameters in the effective dynamics of the aircraft as seen by the pilot. The airplane-alone dynamics are shown in the heavy box-brackets [G] while the control system features are identified explicitly in the block diagram. Notice in particular that, within the bandwidth (and control power/rate) limitations of the augmented system, and assuming primary inner (θ) loop high gain integrity:

- The primary aircraft response to pilot command is almost independent of the aircraft dynamics. It depends only on the control system G_i/G_f (G_f may be partly affected by the need to stabilize the aircraft dynamics, although this may be offset by adjustments in G_i);

- The secondary responses to commands and all responses to disturbances depend primarily on those aircraft dynamic parameters that appear in the various airplane-alone numerators. (Note that such airplane transfer function ratios as $[G_\eta^\theta]/[G_\delta^\theta]$ each contain the airplane characteristic function as denominators, so the denominators cancel leaving only airplane numerators.)

These general facets of highly-augmented aircraft dynamic response help define the key dynamic parameters of most interest for minimum flying qualities studies and performance.

c. <u>Implications of Multiple-Redundant, Fail Operational, Highly-Augmented Flight Control</u>

In many future flight control systems the aircraft without the control system will have dynamics that cannot be controlled by the human pilot. Complete reliance is thus placed on the flight control system to

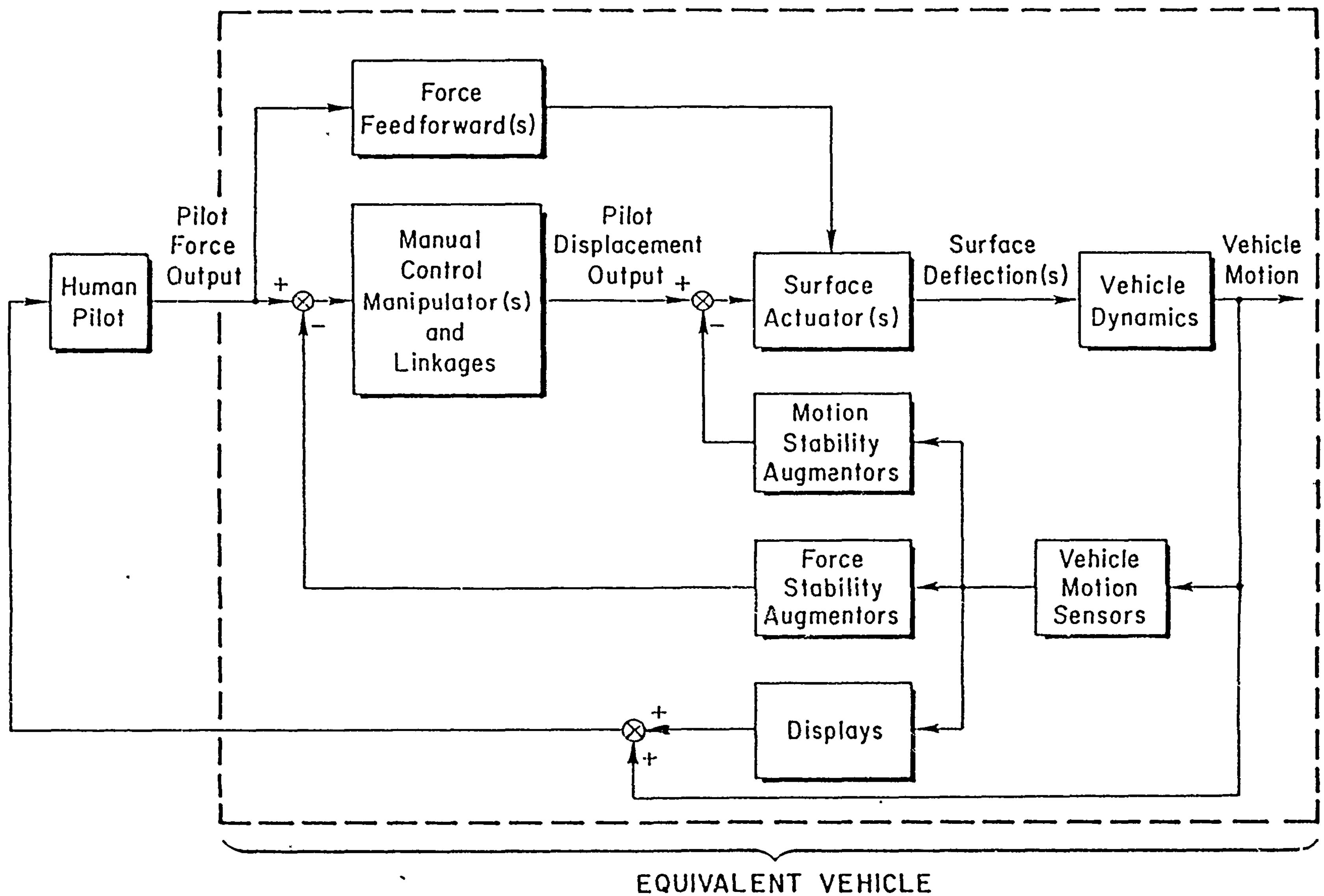
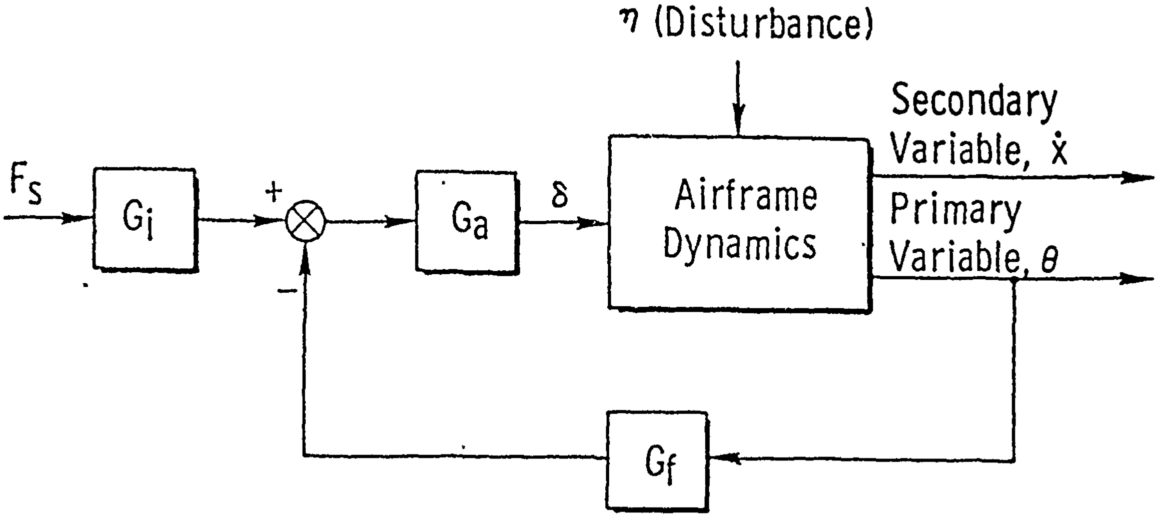


Figure 1. Elements of the "Equivalent Vehicle"



a) • Primary response/command

$$\frac{\theta}{F_s} = \frac{G_i}{G_f}\left\{\frac{G_a G_f\left[G^{\theta}_{\delta}\right]}{1 + G_a G_f\left[G^{\theta}_{\delta}\right]}\right\} \longrightarrow \frac{G_i}{G_f}$$

b) • Primary response/disturbance

$$\frac{\theta}{\eta} = \frac{\left[G^{\theta}_{\eta}\right]}{1 + G_a G_f\left[G^{\theta}_{\delta}\right]} \longrightarrow \frac{\left[G^{\theta}_{\eta}\right]}{G_a G_f\left[G^{\theta}_{\delta}\right]}$$

c) • Secondary response/command

$$\frac{\dot{x}}{F_s} = \frac{\theta}{F_s}\left[\frac{G^{\dot{x}}_{\delta}}{G^{\theta}_{\delta}}\right]$$

d) • Secondary response/disturbance

$$\frac{\dot{x}}{\eta} = \frac{G^{\dot{x}}_{\eta} + G_a G_f\left[G^{\theta\dot{x}}_{\delta\eta}\right]}{1 + G_a G_f\left[G^{\theta}_{\delta}\right]} \longrightarrow \left[\frac{G^{\theta\dot{x}}_{\delta\eta}}{G^{\theta}_{\delta}}\right]$$

Figure 2. Effective Aircraft Dynamics Pilot-Command and Disturbance Input -- Aircraft Response Relationships

always be present at some level of integrity, and to supply some minimum set of aircraft/flight control closed-loop system dynamics. While the systems are expected to be operational in the presence of failures, the failed characteristics are typically quite different from the primary system in an attempt to make the various possible backup FCS's as simple as possible.

Current examples are the X-29 and the Shuttle. The X-29 has two backup possibilities after the initial fail-operational (without degradation) phases for the primary system are exhausted. The first is the DR (digital reversion) mode, which uses the non-failed primary digital system hardware, but with a reduced capability due to control law simplification including some fixed gains. The second is the AR (analog reversion) mode, which substitutes a fail-operational analog FCS of somewhat reduced capacity for the digital system. Both backups suffer flying quality degradations which, as a practical matter, amount to the minimum flying qualities conditions available for this airplane.

The Shuttle has two types of FCS backup possibilities. The first is "down-moding" the primary system (which comprises, in general, a quad computer plus quad+ associated sensors coupled to triplex actuation) mainly by reduced system gain changes. It was originally intended to provide for relief in case aerodynamic characteristics or particular payload combinations led to a system instability. As operational experience is gained the need for down-moding decreases -- yet <u>it will always be necessary in the development phases of almost any airplane</u> and, as such, requires some consideration in the specification of minimum flying qualities. In this case it is the developmental phase rather than a mission task that is to be considered as the basis of minimum characteristics.

The second Shuttle backup is a true backup system. It comprises a single backup computer, programmed with different software. The control laws are simpler, the stability margins are different, etc. This system may be engaged when the status of primary system elements is such as to make future flight safety a critical issue. The system is single-thread and, once engaged, primary cannot be regained. The backup condition is formally defined as "Level 2" on the Shuttle (again, there is no further

place to go!). The minimum flying qualities corresponding to this definition of Level 2 are given primarily in terms of the FCS stability margins -- e.g., 3 dB gain margin and 20-25 degrees phase margin. The minimum flying qualities are then de-facto defined as whatever the resulting effective vehicle dynamics are.

These examples provide additional focus on types of "minimum flying qualities" for future vehicles equipped with multiple redundant controls, i.e.,

- "Developmental Phase" minimum flying qualities may be needed for exploratory flights of vehicles with peculiar uncertainties (e.g., trans-atmospheric vehicles). Usually these will permit the full attention of the pilot to be devoted to control, so much of the existing lore on Level 2 boundaries will be applicable.

- Minimum flying qualities that are peculiarly sensitive to control system failure possibilities, possibly expressed in a control system framework, will probably always be needed to define backup modes.

The nature of control system degradations -- i.e., variable to fixed gains, reduced gain system dynamics and, most important of all, reduced effector rate (and/or authority) -- must be taken into account in the determination and specification of minimum flying qualities for this kind of aircraft/FCS.

d. Reconfigurable/Reconstructed Controls

A matter of great current interest for future systems is the possibility of control reconfiguration or reconstruction in the event of failure, battle damage, etc. In these systems, effectors and control apparatus which still retain integrity can be reconfigured in various ways; secondary effectors can be inserted, etc. The resulting effective vehicle dynamics will provide another set of considerations with which minimum flying qualities requirements must contend.

3. Criteria for Minimum Flying Qualities

Many methods currently exist to assess the impact on aircraft flying qualities of the change in a single system or component. The military flying qualities specification (Reference 1) and the MIL Standard that is replacing it (Reference 2) both contain an extensive set of criteria for evaluating the flying qualities Level associated with a particular aircraft dynamic characteristic. Both assume, however, that the flying qualities Level resulting from a degradation in a single element is to be judged with all other elements within their respective Level 1 limits. For example, requirements on short-period damping ratio make no allowances for possible interactions with short-period frequency. Thus, the combined effects of marginal Level 2 low damping ratio and low undamped natural frequency may be far worse than marginal Level 2.

Some flying qualities criteria have been developed that intrinsically account for multiple degradations <u>in a single axis</u>. Examples of these are the alternative pitch response criteria in the Reference 2 MIL Standard, including aircraft bandwidth and Neal-Smith criteria. There are, at present, no such metrics for accounting for simultaneous degradations in flying qualities in <u>more</u> than one axis.

4. The Minimum Flying Qualities Data Base

The effects of changes in multiple parameters on flying qualities, within a single axis, have been studied extensively in the past. For the example of short-period dynamics, this would consist of combined variations in the frequency and damping of the short-period mode, usually in combination with different evaluation tasks.

The data base for assessing multi-axis flying qualities, however, is extremely limited. The only thorough evaluation of varying dynamics in one, two, and three axes was performed for a Master's thesis from the Air Force Institute of Technology (AFIT) in 1962 (Reference 3). This experiment (usually referred to as the Dander experiment or Dander data, after the author) was conducted using a simple fixed-base simulator to obtain handling qualities ratings (using the old Cooper rating scale) for single-

axis dynamics and various combinations of the same dynamics in multiple axes. The task involved compensatory tracking of attitude errors displayed on a screen. The data from this simple experiment have proven valuable for determining the handling qualities degradations that occur when otherwise good (Level 1) single-axis dynamics are flown multi-axis. The only quantitative data available from Reference 3, however, are the pilot ratings themselves. No information on the behavior of the pilot in controlling multiple axes was obtained.

B. EXPECTATIONS FOR PILOT PERFORMANCE

The classical theory of pilot-vehicle system dynamics is based on the well-known "Crossover Model" (Reference 16). In a specified task with the effective vehicle dynamics described by the transfer function Y_c, the crossover model states that the pilot will adapt his behavior, represented by the describing function Y_p, to achieve a particular open-loop describing function and near maximum performance. The crossover frequency of the open-loop pilot-vehicle describing function Y_pY_c will be maximized for the task when the pilot's full attention is focused on the task.

In conditions of divided attention -- either between control tasks (i.e., axes) or between control and non-control tasks -- performance degradations can be expected when compared to the full-attention case. In terms of the pilot-vehicle system, some general hypotheses can be stated for the divided-attention multi-axis situation when contrasted with the full-attention, single-axis case:

1) It is expected that overall pilot workload will increase, whether it is measured quantitatively in terms of overall control activity, or qualitatively in terms of Handling Qualities Ratings;

2) The overall performance in the primary axis is expected to degrade, associated with a reduction in crossover frequency, increase in phase margin, and increase in rms error;

3) Given comparable urgency to complete the multi-axis tasks, the pilot will focus most of his attention on the most degraded axis.

C. OBJECTIVES OF THE PRESENT STUDY

As aircraft and their missions become more sophisticated, it is imperative that the flying qualities specifications reflect any associated changes in control tasks and pilot role. The logical next generation of specifications will impose a full mission-oriented approach to flying qualities. Aircraft missions will be defined in terms of mission tasks or task elements, and criteria will be tailored for these task elements to encompass all components of the pilot/aircraft system (cockpit controls, displays, vision aids, etc.). A major step in the development of a mission-oriented specification will be the proper accounting for the <u>overall</u> flying qualities <u>for the overall mission element</u>. If the task requires continuous tracking in all axes, the criteria must reflect this; if, in addition, the cockpit environment is expected to be high-workload or limited by visibility, the requirements for <u>overall</u> flying qualities must change to suit the pilot/aircraft/mission task combination.

There is, unfortunately, a dearth of data and methodology needed to achieve these ends. Steps to improve matters are the major motivation of the current project. The data and analyses reported in this volume are expected to significantly increase the available data, while matters of methodology and pilot modeling are dealt with in Volumes II and III.

As the empirical element of the combined analytical-empirical thrust on the broad front of minimum flying qualities, a moving-base simulation was conducted on the U.S. Air Force's Large Amplitude Multimode Aerospace Research Simulator (LAMARS) at Wright-Patterson AFB, OH. The primary focus of the simulation was to generate a data base for minimum flying qualities, with emphasis on the effect of multiple degradations in two axes (pitch and roll) compared to single-axis performance, and in combination with a high-workload, divided-attention cockpit environment.

A matrix of aircraft dynamic models, represented for ease of implementation and measurement by linear transfer functions, was developed to cover Level 1, 2, and 3 flying qualities (as defined by Reference 2) in each axis. An additional simple airspeed model was included to force the pilot to control a second display with a separate controller.

The mission tasks were representative of low-altitude, high-speed flight in a fighter-type aircraft. For the primary task, pitch and roll attitude error signals were generated using a sum of sine waves and displayed to the pilot on a Head-Up Display (HUD). The pilot's objective was to minimize these errors to the extent possible given a certain set of aircraft dynamics. The forcing function signals were random-appearing, with relatively invariant run-to-run amplitude levels. This was representative of a compensatory tracking task (Reference 4): the pilot is required to exert continuous closed-loop control to compensate for the displayed errors. The errors are sent to the HUD only, i.e., they do not drive the aircraft model itself. The setup and structure for the compensatory tracking task are described fully in Appendices A and B.

While the pitch and roll compensatory tracking tasks were primary, several other tasks were added: 1) a third axis for compensatory tracking using the throttle; 2) a head-down managerial task using a display in the cockpit; and 3) an out-the-window, aggressive visual low-altitude task that contained components to emphasize pitch-only, roll-only, and combined pitch-roll maneuvering. These additional tasks are documented in detail in Appendix B.

Prior to the moving-base simulation, the aircraft dynamics were compared with various existing and proposed flying qualities criteria to estimate the expected flying qualities Levels, and if possible, the expected range of Handling Qualities Ratings (HQRs, based on the Cooper-Harper pilot rating scale, Reference 5). All such criteria are single-axis (i.e., either pitch alone or roll alone), with no methods for accounting for multiple-axis operation, or for the addition of divided attention. The techniques available for estimating multiple-axis HQRs were optimal-control pilot model matches (e.g., Reference 6), requiring comparisons of the output of these matches with similar values for the Dander data base; and the multi-axis "Product Rule" (Reference 7), which is a method for combining single-axis HQRs into an overall multi-axis HQR. These are both covered in Volume II.

A preliminary fixed-base simulation was conducted at Systems Technology, Inc. (STI) prior to the moving-base simulation. This served three

purposes: 1) it provided an initial assessment of the single- and multiple-axis handling qualities of the candidate models; 2) it allowed for refinements of the tasks and data acquisition requirements; and 3) it generated a small data base for comparison with the later LAMARS data.

D. ORGANIZATION OF THE REPORT

The report is organized as follows: Section II describes the primary pitch and roll dynamic model configurations developed for the simulation. Section III compares these effective vehicle dynamics with various current and proposed handling qualities criteria, both single- and dual-axis, to make estimates of the expected flying qualities Levels (and, to the extent possible, HQRs); examples of the application of some of these criteria are also presented, such as the optimal control pilot model (OCM) techniques described in Volumes II and III.

Section IV presents the results of the initial fixed-base simulation evaluation by comparing the estimates of Section III with actual HQRs and pilot performance measures; impact of these results on the development of the moving-base simulation plan is also discussed.

Section V shows the revised estimates for Levels and HQRs using the fixed-base results as a guide. Section V also presents several mathematical regression formulas for estimating HQRs using measures of aircraft dynamics.

Section VI analyzes the data from the moving-base simulation. This includes an evaluation of inter- and intra-pilot variations in terms of both pilot opinion (HQRs) and pilot performance; analysis of pilot behavior in performing tracking in one, two, and three axes; comparison of HQRs from the HUD tracking tasks with those obtained for aggressive, low-altitude visual flight tasks; and, finally, comparison of all simulation data -- both quantitative and qualitative -- with the estimates and criteria of Section V.

Section VII summarizes the recommendations for making estimates of multiple-axis handling qualities, including the OCM, Product Rule, and

mathematical regression methods. Section VIII presents the major conclusions of this study.

Appendices A and B document the fixed-base (STI) and moving-base (LAMARS) simulations, respectively. Appendix C presents additional analysis of pilot dynamics in the presence of multiple degradations, including pilot models extracted from the simulation performance data.

The analytical elements of estimating pilot behavior in conditions of minimum flying qualities are presented in Volume II. Volume III documents the procedures followed in implementing and operating a personal-computer-based optimal control model.

SECTION II

MATRIX OF PRIMARY CONFIGURATIONS

A. SELECTION CRITERIA

A limited number of pitch and roll dynamic models were chosen for this study. It was necessary to keep the total number of such cases relatively small, because every configuration was to be evaluated in the HUD tracking task single-axis, then in every possible two-axis combination, and then in combinations with a third axis or with a divided-attention task. In addition, all permutations ere to be evaluated in a separate task. Clearly, an extensive list of pitch and roll configurations would result in an unmanageably large matrix.

The effective aircraft dynamic configurations were represented by constant-coefficient transfer-function models. This form simplified the mechanization of the configurations for simulation, allowed a systematic variation in the parameters, and made for straightforward comparisons with handling qualities criteria. The dynamics for the pitch and roll cases were selected with the intent of producing at least one case within each of the Levels 1, 2, and 3 definitions based on the MIL-STD-1797 (Reference 2) criteria.

Five pitch and four roll transfer function models were selected as the primary variation cases. Even with such a small number of cases, the total evaluation matrix is very large: each case must be flown single-axis (5 + 4 or nine cases); in all combinations two-axis (5 * 4 = 20); single- and dual-axis with at least one throttle sidetask (5 + 4 + 20 = 29), and single- and dual-axis with at least one noncontrol sidetask (29 more), for a total matrix, <u>as a minimum</u>, of 87 different configurations to be evaluated. It was recognized from the outset that certain combinations within such a matrix would probably be unflyable (e.g., a Level 3 pitch case with a Level 3 roll case and either sidetask); on the other hand, it was also anticipated that several repeats would be necessary for some cases, and that questions would arise in the course of the simulations that would justify the addition of other dynamic models and hence an increase in the matrix size. For these reasons, a basic matrix of five pitch and four

roll aircraft models seemed reasonable.

Responses consistent with a fighter-type (Class IV, Reference 2) aircraft were chosen. Effects found with larger aircraft, such as pilot offset from the center of gravity, were avoided; in addition, secondary characteristics that might complicate the analysis of the results, such as phugoid dynamics and Dutch roll oscillations, were minimized or removed altogether. Detailed descriptions of the actual aircraft models as they were mechanized are given in Appendix A for the STI fixed-base simulation and Appendix B for the LAMARS simulation. This section will describe the controlled elements of interest in pitch and roll (i.e., θ/θ_c for pitch, ϕ/ϕ_c for roll) and how the dynamics for each case were chosen.

B. PRIMARY CONFIGURATIONS

1. Pitch Configurations

The dynamics for the primary evaluation configurations are listed in Table 2.* In pitch, the transfer function of a two-degree-of-freedom, short-period aircraft was used. The θ/θ_c transfer function was of the form:

$$\frac{\theta}{\theta_c} = \frac{\omega_{sp}^2/1.25\ (s + 1.25)e^{-\tau s}}{s[s^2 + 2\zeta_{sp}\,\omega_{sp}s + \omega_{sp}^2]}$$

Most of the pitch cases were designed to represent, more or less, the dynamics of several configurations evaluated in a flight experiment conducted by Calspan on the USAF variable-stability NT-33. This experiment (Reference 8) investigated the effects of added dynamics on handling qualities for precision pitch tasks. For the current experiment, the flight conditions and numerator characteristics were chosen to match those of the NT-33 used for the majority of the Reference 8 flight evaluations (250 kt

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*As Table 2 indicates, the primary cases had different identifiers (case numbers) for the fixed-base experiments at STI and the moving-base experiments on the LAMARS. Through the early portions of this report, the STI case numbers will be used; the LAMARS numbers are used when the LAMARS results are introduced. In either case, it will be clear at all times which identifier is being used.

TABLE 2. DYNAMICS OF PRIMARY EVALUATION CONFIGURATIONS

			ROLL	$1/T_R$ (rad/sec)	100†	0.5	0.5	4.0
				τ (sec)	0.0	0.067	0.20	0.067
PITCH				STI Case I.D.	J	B	G	D
ζ_{sp} (−)	ω_{sp} (rad/sec)	τ (sec)	STI Case I.D.	LAMARS Case I.D.	A	B	C	H
4.526*	11.18	0.0	11	1				
0.80	5.0	0.033	3	2				
0.80	5.0	0.20	8	4				
0.18**	5.0	0.033	2	5				
0.18	5.0	0.20	5	6				

*For LAMARS simulation, this gives $\theta/\theta_c = 1/[s(s + 100)]$; For STI simulation, a pure $\theta/\theta_c = 1/s$ was used.

**$\zeta_{sp} = 0.20$ for STI simulation case.

†For STI simulation, $1/T_R = \infty$, i.e., $\phi/\phi_c = 1/s$.

Transfer Function Forms:

$$\text{Pitch:} \quad \frac{\theta}{\theta_c} = \frac{\omega_{sp}^2/1.25\ (s + 1.25)e^{-\tau s}}{s[s^2 + 2\zeta_{sp}\,\omega_{sp}s + \omega_{sp}^2]}$$

$$\text{Roll:} \quad \frac{\dot{\phi}}{\phi_c} = \frac{1/T_R\ e^{-\tau s}}{s(s + 1/T_R)}$$

(129 m/s) airspeed at 9500 ft (2900 m) altitude). At this condition the frequency of the pitch attitude zero $1/T_{\theta_2}$ is 1.25 rad/sec.

The first pitch transfer function model on Table 2 (STI Case 11, LAMARS Case 1) was configured to provide ideal response characteristics, i.e., k/s dynamics. For the fixed-base simulation, where path dynamics were not modeled, a pure 1/s transfer function was employed. Since the moving-base simulation required a full set of transfer functions for three degrees of freedom, a slightly modified form was required. The damping ratio and natural frequency of the short-period mode were set so that the short-period consisted of two firs -order roots, one at 1.25 rad/sec (to cancel the pitch attitude zero) and one at 100 rad/sec (selected somewhat arbitrarily, but at a sufficiently high frequency that the effective transfer function is approximately k/s).

The second pitch transfer function model in Table 2 (STI Case 3, LAMARS Case 2) is the baseline "airplane-like" configuration. This case, with an added time delay of 0.033 sec to approximate elevator servo-actuator lags, is similar to configuration 2D in Reference 8. It was included to represent a good conventional airplane. As the next section of this report will show, this case was expected to provide Level 1 handling qualities when flown single-axis.

STI Case 8 (LAMARS Case 4) is the good baseline airplane with added time delay (τ = 0.20 sec). STI Case 2 (LAMARS Case 5) is the baseline with reduced short-period damping, comparable to configuration 5A in Reference 8. STI Case 5 (LAMARS Case 6) combines both low damping and high time delay.

2. Roll Configurations

The roll dynamics were configured to provide a conventional roll subsidence mode, $1/T_R$, with neutral spiral ($1/T_S = 0$) characteristics, and no Dutch roll coupling effects. In the roll transfer function, the Dutch roll pole was perfectly canceled by the roll numerator zero, resulting in a transfer function of the following form:

$$\frac{\phi}{\phi_c} = \frac{1/T_R \; e^{-\tau s}}{s\,(s + 1/T_R)}$$

The first roll configuration in Table 2 (identified as STI Case J, LAMARS Case A) was developed to provide ideal response dynamics, i.e., k/s in roll. For the fixed-base simulation at STI, a pure transfer function of 1/s was used. For the moving-base simulation, however, more complete lateral dynamics were required, so the roll mode inverse time constant, $1/T_R$, was set at 100 rad/sec, far above the expected pilot/vehicle crossover frequency. Hence this configuration was essentially k/s for both simulations.

The baseline "airplane-like" configuration, i.e., dynamics representative of a real airplane, was STI Case D (LAMARS Case H). This case had $1/T_R = 4$ rad/sec, with $\tau = 0.067$ sec approximating aileron servoactuator lags. From this, STI Case B (also LAMARS Case B) had reduced roll damping, and STI Case G (LAMARS Case C) had both reduced roll damping and additional time delay.

C. ADDITIONAL CONFIGURATIONS

During both the fixed-base and moving-base simulations, several additional pitch and roll configurations were evaluated. This was done either in an attempt to elicit different Handling Qualities Ratings (HQRs) from one or more of the pilots, or to investigate some issue not addressed by the primary configurations. As a result, the actual matrix of configurations flown is much larger than that listed in Table 2. These additional configurations provide important data for investigating the primary objectives, and they are referred to occasionally throughout this report. They were not, however, intended to be part of the primary matrix and hence the number of HQRs for any one configuration -- and especially for multiple combinations of these configurations -- is quite small. The dynamics for these additional configurations are documented in Appendices A and B.

SECTION III

ESTIMATED HANDLING QUALITIES FOR PRIMARY CONFIGURATIONS

A. OBJECTIVES

A major objective of the present study has been the evaluation of existing handling qualities criteria for their effectiveness at estimating handling qualities. Since the focus of the study is the effect on handling qualities of multiple degradations, the primary interest has been on metrics for combining expected flying qualities Levels (or HQRs) in more than one axis into an overall Level or HQR.

All of the requirements in the soon-to-be-retired military specification, MIL-F-8785C (Reference 1), and most of the requirements in its replacement, MIL-STD-1797 (Reference 2), provide for assessment of a single element in the aircraft response, assuming all other elements are satisfactory. As an example, compliance with the short-period criteria based on Control Anticipation Parameter (CAP) is required in MIL-F-8785C, and they are the "preferred form" in MIL-STD-1797. Compliance with MIL-F-8785C requires separate compliance with the short-period frequency (Para. 3.2.2.1.1 in Reference 1), damping (Para. 3.2.2.1.2), and response (time) delay (Para. 3.5.3) limits. It is implicitly assumed that if all parameters meet the Level 1 limits, the overall aircraft short-period response is Level 1. This is clearly correct if the individual criteria are appropriate. It is <u>further</u> assumed that the overall aircraft is Level 2 if any one parameter fails the respective Level 1 limit. What is <u>not</u> clear is what the flying qualities might be if <u>more</u> than one parameter is Level 2.

The military standard (Reference 2) has taken a first step toward accounting for some of these multiple degradations. For example, requirements on short-period frequency and damping have been combined into one criterion (Para. 4.2.1.2 in Appendix A of Reference 2), as shown in Figure 3. The next logical step in this process is an adjustment of the boxes in Figure 3 to disallow combinations of marginal characteristics, such as low damping and low frequency -- i.e., a rounding of the corners for each of the Levels.

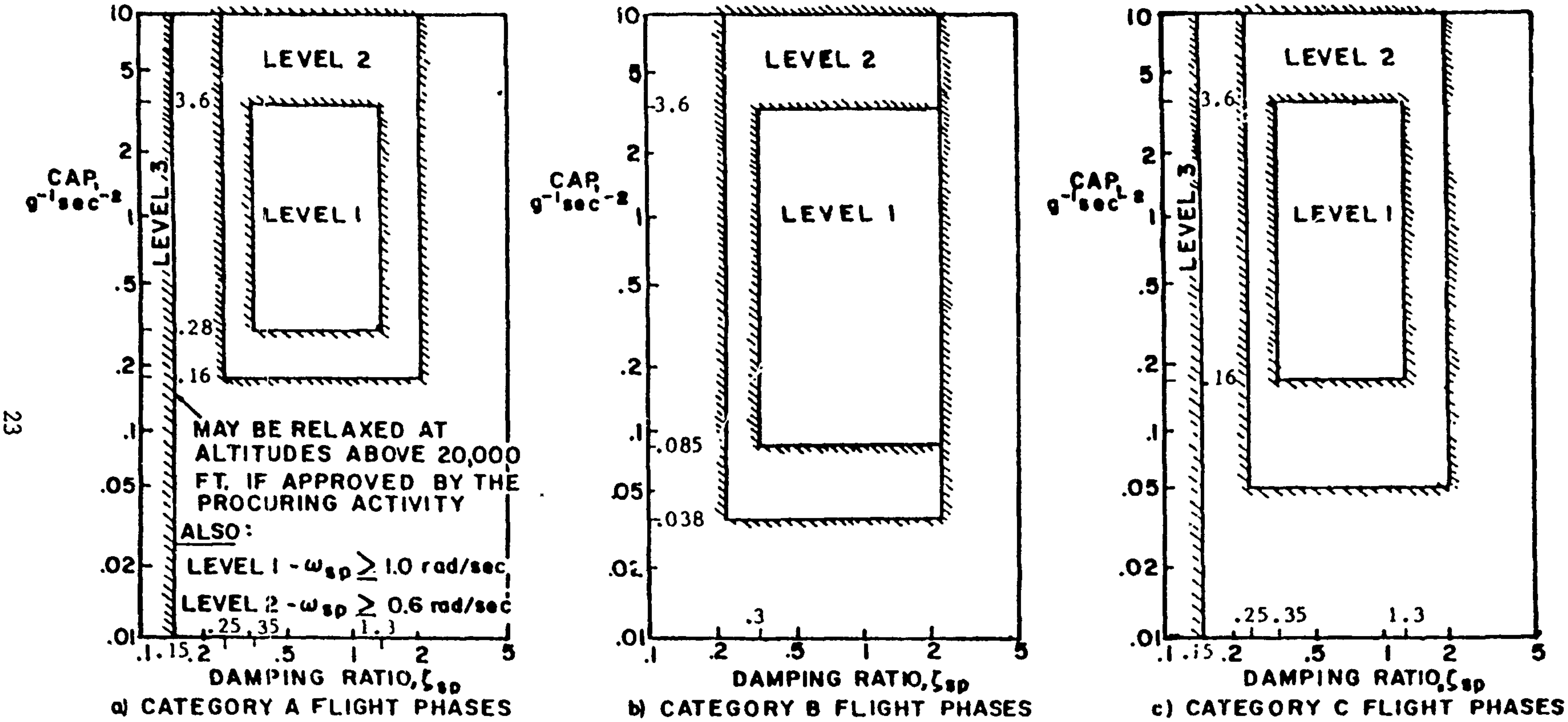

Figure 3. Short-Period Dynamic Requirements (from Ref. 2)

A further step in accounting for multiple degradations that has been taken in the military standard is the incorporation of alternative criteria based on pilot/vehicle dynamics. For the short-period requirements, these include the bandwidth and Neal-Smith criteria. Such techniques attempt to evaluate the characteristics of the overall airplane response and hence, by definition, include all of the equivalent-airplane parameters covered by the classical requirements.

Nowhere in the current or proposed specifications, however, is there information on how to assess the overall flying qualities when several axes are degraded -- for example, if both pitch and roll handling qualities are Level 2. Nor is there insight into methods for accounting for high-workload operations, whether the aircraft alone is degraded or not. In such situations, the airplane-alone flying qualities may very well be ideal, but the pilot may be so saturated by divided-attention tasks that the overall effectiveness of the pilot-plus-airplane system is degraded.

In this section several of the existing and proposed handling qualities criteria are applied to the primary pitch and roll configurations described in Section II. The objective here is to evaluate these configurations single-axis and, to the extent possible, in all multi-axis combinations, prior to the simulations. This will assess all of the chosen criteria for their predictive ability, at least as they relate to the tasks, facilities, and dynamics used in this study.

All criteria were applied for Category A operations. This was considered appropriate since the primary task in both simulations (documented in Appendices A and B) was precision HUD tracking, representative of Category A Flight Phases. In the moving-base simulation, several low-altitude tasks corresponding to ground attack or terrain following (both Category A Flight Phases) were also flown. An estimate of the expected pilot behavior in terms of the crossover model (Reference 16) is also presented in this section.

B. SELECTION OF HANDLING QUALITIES CRITERIA

Handling qualities criteria for both pitch and roll were selected that provide an estimation of the flying qualities Level (defined as in References 1 and 2) for each transfer-function model of Section II. For some criteria, as discussed above, several Levels may be specified, based on comparison of each element of the transfer function with individual limits.

Wherever possible, attempts were made to also estimate a range of expected Handling Qualities Ratings (HQRs). For example, the bandwidth boundaries in Reference 2 include all of the parameters involved in the bandwidth criterion, and therefore, some estimate of an HQR can be made based on the location of a configuration within the boundaries. On the other hand, the Neal-Smith criteria in Reference 2 simply state Levels based on certain parameters, with no indication of sensitivity of HQR to these parameters. (This is in contrast to the original Neal-Smith criteria as they were developed and documented in Reference 8; in that report, the two primary parameters are crossplotted and an accurate assessment of actual expected HQR, as well as Level, is possible.)

The only criteria that allow an evaluation of multi-axis flying qualities (the optimal control pilot model and the Product Rule) are less well-known than most of the single-axis criteria; both of these are documented in Volume II of this report.

The list of criteria selected was not intended to be exhaustive, but rather to be representative of the state of the art in the field of handling qualities.

1. Pitch Criteria

The primary pitch-axis handling qualities criteria are the short-term response requirements presented as alternatives in Para. 4.2.1.2 of the

military standard, Reference 2. These consist of the following:*

- CAP or $\omega_{sp}^2/(n/\alpha)$, ζ_{sp}, τ_θ
- $\omega_{sp}T_{\theta_2}$, ζ_{sp}, τ_θ
- Transient peak ratio, rise time, effective delay
- Bandwidth, time delay
- Pilot-in-the-loop criteria (modified Neal-Smith)

In addition, the original Neal-Smith criteria of Reference 8 were applied as a result of problems with application of the modified Neal-Smith criteria of Reference 2.

The optimal control pilot model (OCM) approach described in Volume III was applied to all of the primary configurations. This approach involves determination of a cost function, J, for the tracking task and estimation of the expected HQR from a cost function/rating correlation in Reference 6.

The final pitch-axis estimation technique involved construction of a table of verbal descriptions for each of the configurations, using the terminology of the Cooper-Harper pilot rating scale and the expertise of a handling qualities engineer. This technique required that the experienced engineer define the model in terms of a set of pilot- and aircraft-centered adjectives; the table was then used to compare the adjectives with the HQR scale and make a preliminary judgement of the aircraft's flying qualities. This is clearly a highly subjective technique that is strongly affected by the experiences and personal biases of the engineers involved. It is, however, an effective initial method for handling qualities assessment, and its application here is an attempt to quantify the knowledge base of an experienced engineer as a human expert system.

2. Roll Criteria

The number of applicable roll-axis criteria is quite small when compared to pitch. This is a reflection of both the more generally straight-

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*An additional alternative in Reference 2, based on drop-back and Nichols chart boundaries, was not applied here. The time- and frequency-response boundaries associated with this alternative are intended for fly-by-wire control law design optimization and overall flying quality Levels have not been established.

forward characteristics in roll compared to pitch, and the perhaps excessive fascination with pitch flying qualities in recent years.

The primary roll criteria were those specified in MIL-STD-1797 (Para. 4.5), limited, in this case, to the roll mode (4.5.1.1) and time delay (4.5.1.5) requirements. Other related requirements in Reference 2 deal with roll oscillations, roll/yaw interactions, lateral accelerations 2 at the pilot's station, etc. Any handling qualities problems due to these issues were alleviated by a combination of high Dutch roll damping, cancellation of the Dutch roll in the roll response, perfect turn coordination, and location of the pilot at the aircraft center of gravity.

Additional criteria for roll were taken from the flight tests reported in Reference 9 (the LATHOS experiments), and, as in the pitch axis, from the application of the optimal control model (OCM) of the human pilot. Finally, adjectival descriptions of the roll configurations were constructed, as described for the pitch cases.

3. Multi-Axis Criteria

There are only two "criteria" applied for the multi-axis situation: the combined pitch/roll estimation of the cost function J from the OCM, and the Product Rule from Reference 7. The latter is not so much a "criterion" as a purely derived method for combining single-axis ratings through a general equation. This approach was applied to all of the relevant single-axis criteria described above where estimates of HQRs, and not just Levels, were possible.

C. APPLICATION OF CRITERIA TO PRIMARY CONFIGURATIONS

As with all such analytical handling qualities techniques, application of the selected criteria at times required considerable engineering judgement. The most critical of these judgments involves the reference control input for all of the military-standard requirements. The version of the military standard as published in Reference 2 specifies that all requirements be referenced to control force for force controllers and deflection for deflection controllers This decision was influenced by

flight experience with advanced aircraft (such as the X-29A), and by the results of a very brief flight experiment (one pilot, one flight), documented in Reference 10, which suggested that the cockpit feel system dynamics should be treated as an element separate from the rest of the aircraft in the evaluation of overall time delay. At the time MIL-STD-1797 was released, Reference 10 had been published, but little follow-on work had been performed.

Since the publication of Reference 10, several ground and flight experiments (including References 11 and 12) have demonstrated that the force feel system is an integral element in the pilot-vehicle system, and therefore that all handling qualities requirements should be referenced to stick force, whether the actual control system uses force or deflection as the command signal. Based on these experiments, the decision was made for this report to compute all handling qualities parameters with the stick feel system dynamics included, since all cockpit controllers used in the simulations are deflection sensing.

For the STI simulation, the stick feel system dynamics had damping ratios of 0.7 in pitch and 0.5 in roll, and natural frequencies of approximately 15 rad/sec in pitch and 16 rad/sec in roll. (As discussed in Appendix A, for most of the STI simulation a McFadden control loader was employed with linear feel dynamics. For a small subset of the simulation, however, an STI stick with nonlinear dynamics was used. It has been assumed that the dynamics of the stick as mechanized on the McFadden loader are appropriate here.)

MIL-STD-1797 requires the application of lower-order equivalent systems for the classical requirements (e.g., CAP, damping, and equivalent time delay). Since the dynamics of the primary configurations are already lower-order in form (Table 2), no further order reduction was attempted. Addition of the stick force feel system to these transfer functions will affect all of the "equivalent" dynamics somewhat, but this effect should be small and has been neglected here for clarity. It is reasonable to assume that the feel system will appear in the "equivalent" system

primarily as an increase in time delay, so it has been included in the computation of equivalent time delay.

Throughout the discussion that follows, the STI simulation case numbers (Appendix A) will be used. It may be helpful to refer occasionally to the list of configurations in either Table 2 or Appendix A.

1. Pitch Criteria

a. Criteria from MIL-STD-1797

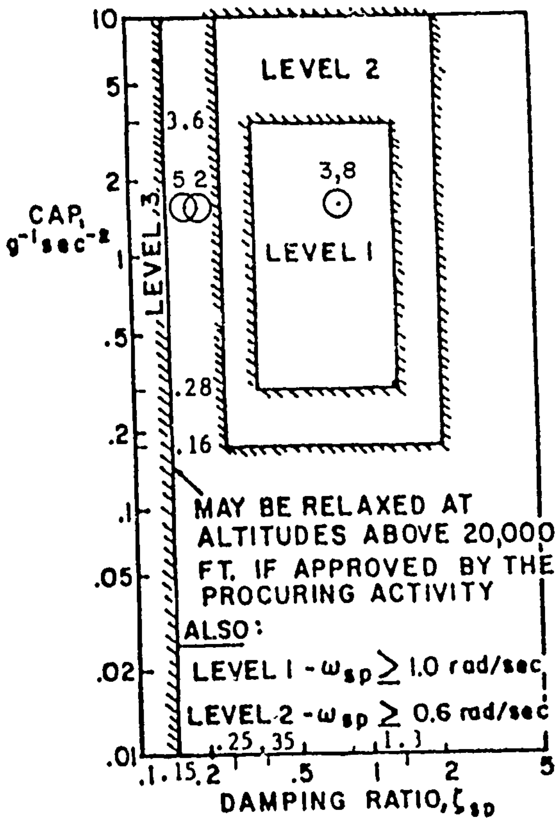
The primary pitch configurations from Table 2 are compared with the short-term pitch response handling qualities criteria of MIL-STD-1797 in Figure 4. Case numbers given in Figure 4 correspond to the STI simulation cases.

Figure 4a is the CAP boundary (where CAP = $\omega_{sp}^2/(n/\alpha)$). Four of the five primary configurations are plotted on this requirement; the fifth, STI Case 11, is the pure k/s case and hence does not have conventional short-term frequency and damping, and therefore cannot be included on this requirement. All of the other cases have adequate short-term frequency, but Cases 2 and 5 are expected to be Level 3 due to low damping.

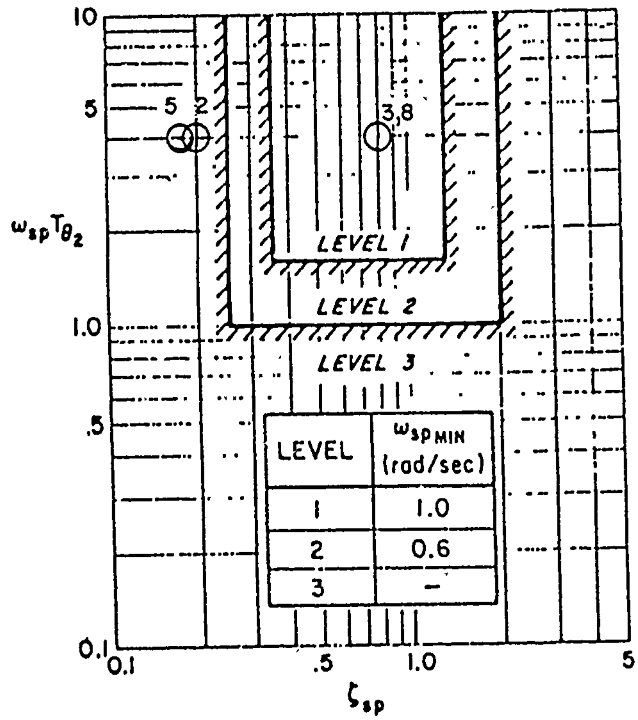
The requirements on $\omega_{sp}T_{\theta_2}$ (Figure 4b) show the same story, as is expected since the criteria of Figs. 4a and 4b are closely related.

Both the CAP and $\omega_{sp}T_{\theta_2}$ criteria also require specification of equivalent time delay, and this is listed in Figure 4c. The MIL-STD-1797 limits on equivalent time delay are 0.10 sec for Level 1, 0.20 sec for Level 2, and 0.25 sec for Level 3. Based solely on time delay, Cases 2 and 3 will be Level 2 and Cases 5 and 8 are worse than Level 3 (the time delay for these cases is beyond the Level 3 limit).

Requirements for Transient Peak Ratio are based on the response of pitch rate to a step control input and are defined at the top of Figure 4d. Values for the individual parameters, and estimated flying qualities Levels, are tabulated on the bottom part of Figure 4d. Based on this set of criteria, Cases 11 (k/s) and 3 are expected to be Level 1; Case 2 is Level 2 based on transient peak ratio; and Cases 5 and 8 have effective



a. CAP vs. ζ_{sp}

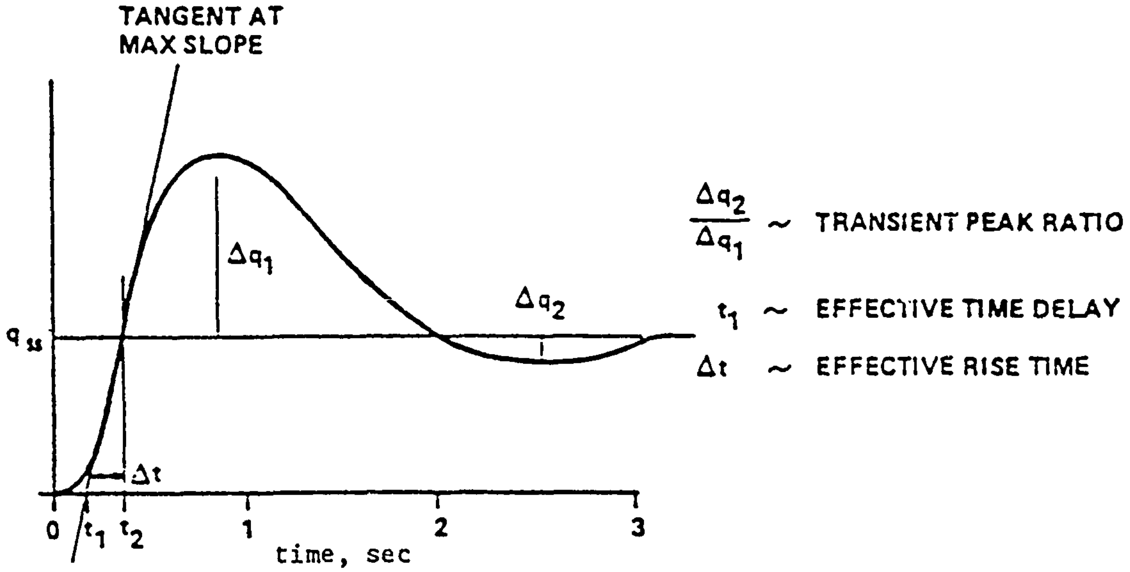


b. $\omega_{sp}T_{\theta_2}$ vs. ζ_{sp}

CASE	τ_θ	LEVEL
11	0.091	1
3	0.124	2
8	0.291	>3
2	0.124	2
5	0.291	>3

c. Equivalent Time Delay

Figure 4. Comparison of Primary Pitch Configurations with MIL-STD-1797 Criteria (STI Case Nos.)

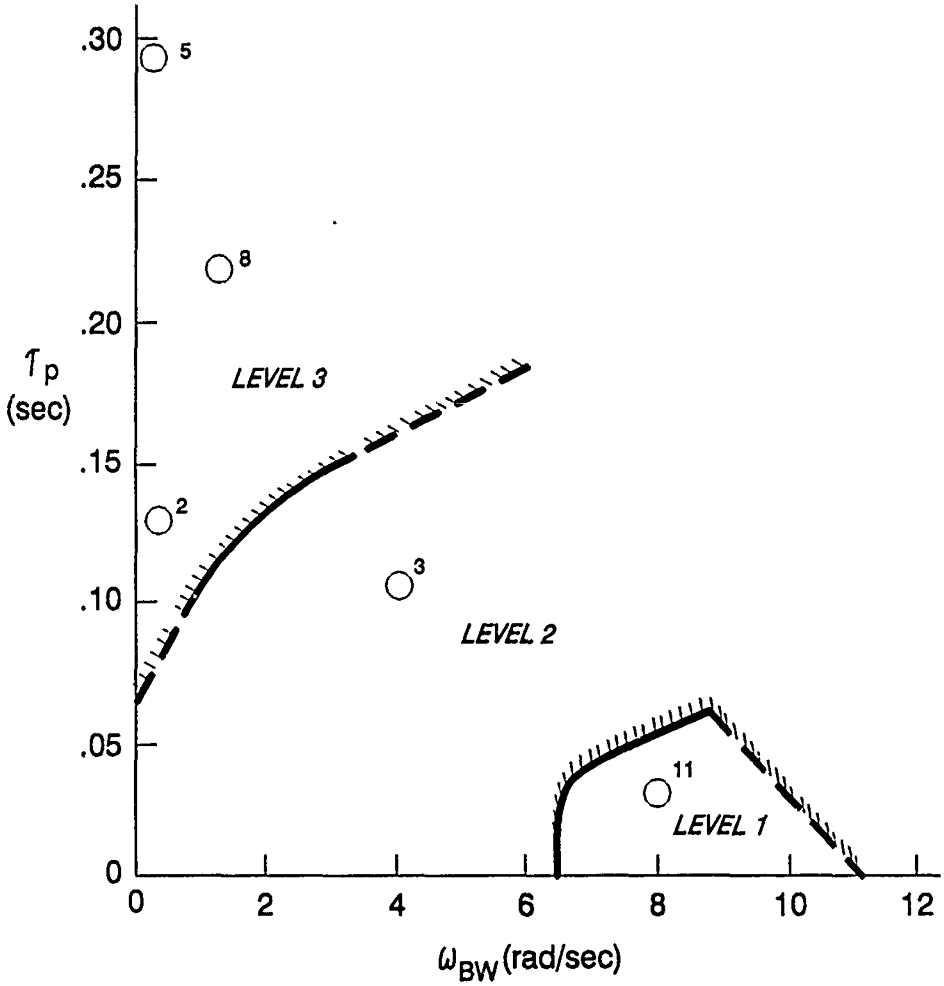


LEVEL	max t_1(sec)	max $\Delta q_2/\Delta q_1$	min Δt(sec)	max Δt(sec)
1	0.12	0.30	0.021	1.185
2	0.17	0.60	0.0076	3.79
3	0.21	0.85	—	—

	$\Delta q_2/\Delta q_1$		t_1(sec)		Δt(sec)	
CASE	VALUE	LEVEL	VALUE	LEVEL	VALUE	LEVEL
11	0.055	1	0.02	1	0.193	1
3	0.015	1	0.11	1	0.082	1
8	0.015	1	0.26	>3	0.10	1
2	0.527	2	0.11	1	0.063	1
5	0.564	2	0.27	>3	0.058	1

d) Transient Peak Ratio, Rise Time, Effective Delay

Figure 4. (Continued)



CASE	$\lvert\theta/\theta_c\rvert_{max}$ (dB)	LEVEL
11	0.0	1
3	8.8	2
8	24.6	3
2	*	3
5	*	3

*Could not meet -3 dB droop requirement for these cases.

f. Pilot-in-the-Loop Criteria

Figure 4. (Concluded)

time delays beyond the Level 3 limit (in addition, Case 5 has a Level 2 value of transient peak ratio).

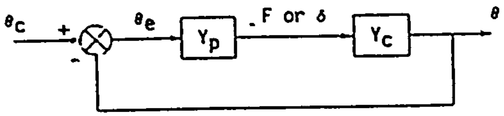
The bandwidth criteria, Figure 4e, allow for an estimation of both Level and HQR, the latter by assessing the proximity of each of the cases to the nearest Level boundaries. On this basis, Case 11 should be Level 1 (estimated HQR = 2-2.5); Case 3 is Level 2 (estimated HQR = 5-5.5); Cases 2, 8, and 5 are at least Level 3, with Case 5 probably beyond Level 3 (estimated HQRs, respectively, are 6.5-7, 8-9, and 9-10).

The pilot-in-the-loop (modified Neal-Smith) criteria of Reference 2 require some interpretation and amplification. Figure 4f tabulates the compliance with these criteria; only Case 11 has sufficiently low closed-loop resonance to meet the Level 1 limit of 3 dB, while Case 3 is Level 2, Case 8 is Level 3, and the requirements for applying the criteria could not be met for the other two configurations.

The definitions of the closed-loop criteria are reprinted from Reference 2 in Figure 5. These criteria are based on the original development followed by Neal and Smith in Reference 8 (hence the criteria are usually referred to as the "Neal-Smith" criteria), and follow a simple construction: for flight tasks that require precise control of pitch attitude, the pilot will close a pitch attitude inner loop (with outer path loops around this inner loop as appropriate) with certain goals in terms of the closed-loop response. For compensatory tracking, it is reasonable to assume that the pilot will act as a pure gain operator with some time delay and, if necessary, some additional leads and/or lags to improve performance. Application of the Reference 2 criteria (Figure 5) requires the assumption of a pilot model of this form, with an additional low-frequency integrator if necessary.

Application of the criteria in Figure 5 works as follows: for the pilot-plus-aircraft system, $Y_pY_c = \theta/\theta_e$, with a pilot model as specified on Figure 5, determine the pilot model parameters K_p, T_{p1}, and T_{p2} such that the closed-loop system, θ/θ_c, has -90 deg of phase at a specified frequency (the bandwidth frequency in Figure 5). Further, for Levels 1 and 2, it is necessary that the closed-loop system exhibit no more than $-$ 3dB of droop from 0 to 10 rad/sec, with resonance over this frequency

For pilot control of pitch attitude in the manner sketched.



where Y_c is the transfer function of the aircraft and flight control system, θ_c is an external pitch command, θ_e is pitch attitude error, F is pilot force on the pitch controller, δ is its deflection and Y_p is the analytical pilot model (either form is permitted):

$$Y_p = K_{pe}^{-.25s}\,\frac{(T_{p1}s+1)}{(T_{p2}s+1)} \quad \text{or} \quad K_{pe}^{-.25s}\,\frac{(5s+1)}{s}\,\frac{(T_{p1}s+1)}{(T_{p2}s+1)}$$

a bandwidth, defined by a closed-loop phase of −90 degrees, of

FLIGHT PHASE	BANDWIDTH
Category A	3.5 rad/sec
Category B	1.5 rad/sec
Landing	2.5 rad/sec
Other Category C	1.5 rad/sec

shall be attainable with closed-loop droop no more than −3 dB for Levels 1 and 2 and closed-loop resonance no greater than 3 dB for Level 1, 9 dB for Level 2 over the frequency range from 0 to 10 rad/sec. The pilot model is constrained to the given forms but there are no limits on K_p, T_{p1} or T_{p2}. The requirements apply for both force and deflection pilot control inputs. Figure 66, in the form of a Nichols chart, illustrates these limits The pilot output is force for force controllers (pilot controller force commands the control effectors) and deflection for deflection controllers (pilot controller deflection commands the control effectors).

For Level 3, T_2, the time to double amplitude based on the value of the unstable root, shall be no less than 6 seconds. In the presence of any other Level 3 flying qualities, ζ_{sp} shall be at least 0.05 unless flight safety is otherwise demonstrated to the satisfaction of the procuring activity. T_2 applies to the value of the unstable root: $T_2 = -(\ln 2)/\lambda$ where λ is the value of the unstable root.

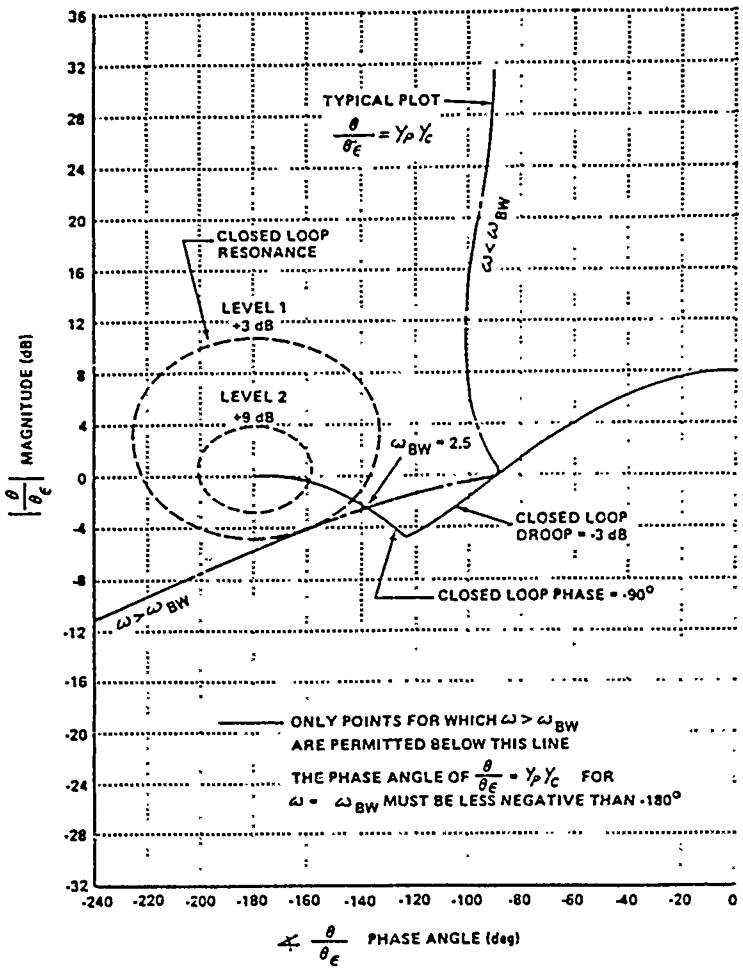


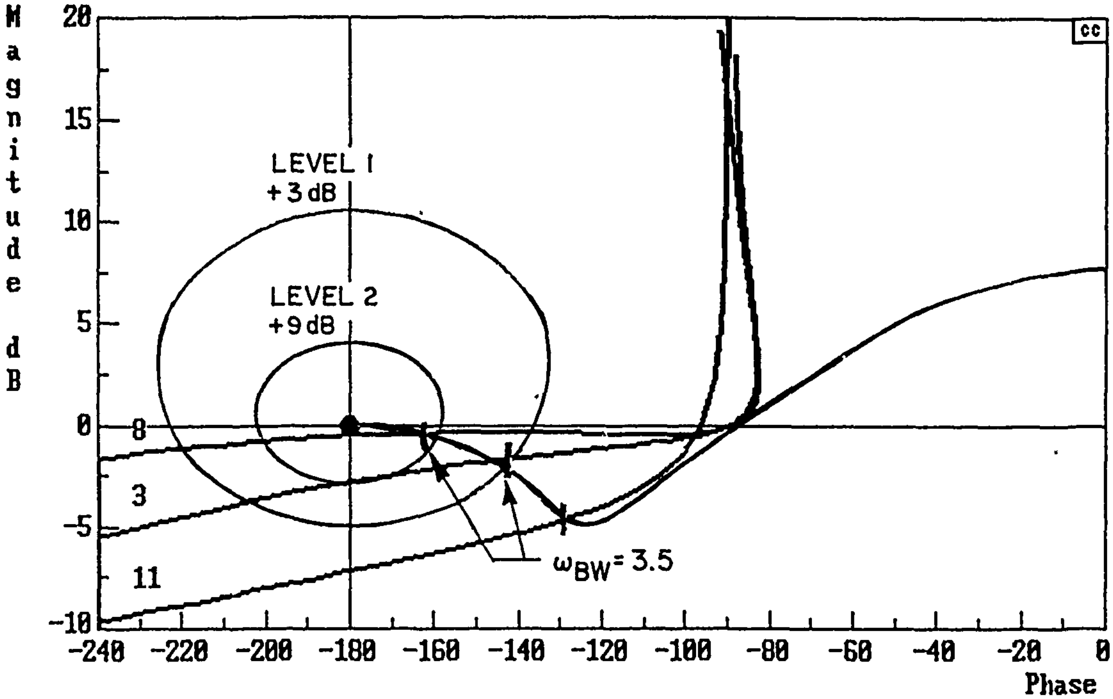
Figure 5. Definition of Pilot-in-the-Loop Criteria from MIL-STD-1797 (Pages 226 and 227 of Ref. 2)

range of 3 dB or less for Level 1 and 9 dB or less for Level 2. (Figure 5 indicates that the aircraft transfer function, Y_c, should be referenced to control deflection for deflection controllers; as discussed previously, this has been demonstrated to be inappropriate and the reference input should always be force, as has been done throughout this report.)

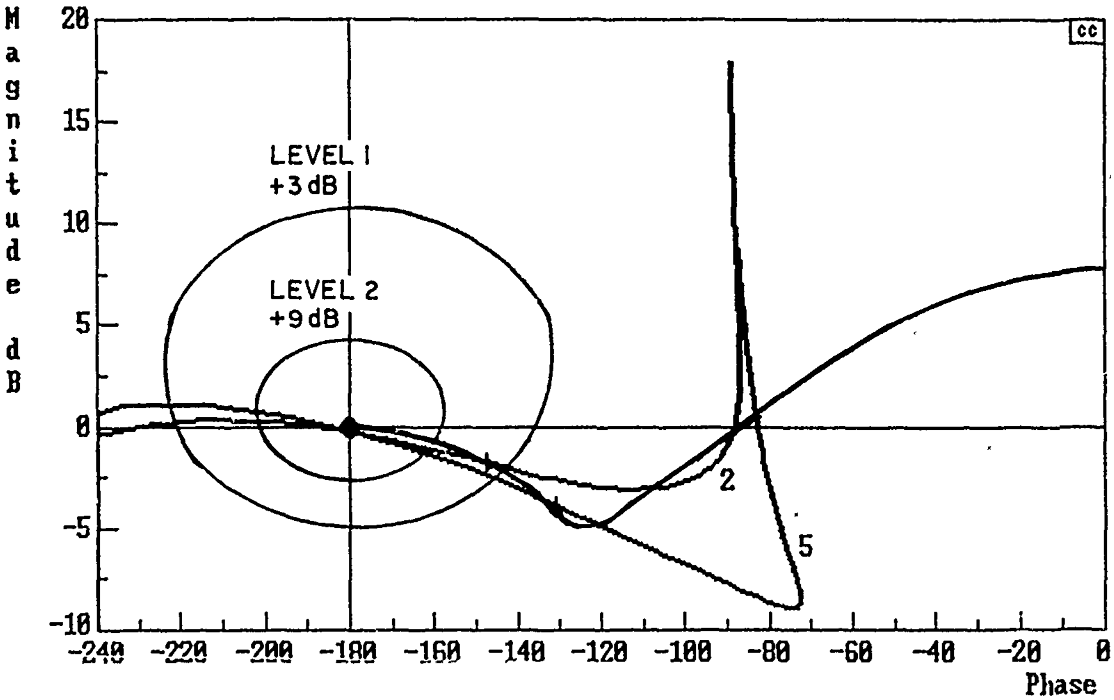
Attempts to determine a closed-loop system that meets all of the requirements of Figure 5 were unsuccessful for Cases 3, 8, 2, and 5; for the last two cases, no pilot lead/lag would reduce the mid-frequency droop to less than -3 dB, and therefore the resonance portion of the criteria could not be applied. This is assumed to mean that these aircraft are estimated to be Level 3.

Figure 6 shows representative plots of θ/θ_e for all of the pitch configurations on the Nichols chart boundaries. The most intriguing response is for Case 3, whose dynamics are based on Case 2D of the flight experiment of Reference 8 (in Reference 8, short-period damping was 0.7 instead of 0.8, and the cockpit control system was force sensing instead of position sensing). This was one of the best airplane configurations in the Reference 8 flight tests, receiving HQRs of 2.5, 3, and 2.5 for pitch tracking. By the criteria of Figure 5, this is expected to be a Level 2 case. Figure 7 shows a Nichols chart for this case <u>without</u> the feel system (i.e., assuming force sensing), and it is still predicted to be Level 2.

Since the present study was not intended as a detailed analysis of the criteria of Reference 2, no attempts have been made to determine the precise causes of the apparent conflicts discussed here. It appears likely, however, that the closed-loop bandwidth specified for Category A Flight Phases (3.5 rad/sec, Figure 5) is too stringent. For example, the source of the modified criteria as adopted in MIL-STD-1797, Reference 13, recommends bandwidth frequencies of 2.5 rad/sec for landing and 1.5 rad/sec for all other tasks, with no reference to the 3.5-rad/sec value. In addition, there is no supporting data in MIL-STD-1797 for this number.



a) Cases 3,8,11 (meet requirements for application)



b) Cases 2 and 5 (cannot meet droop requirements)

Figure 6. Comparison of STI Primary Pitch Cases With Pilot-in-the-Loop Criteria of Ref. 2

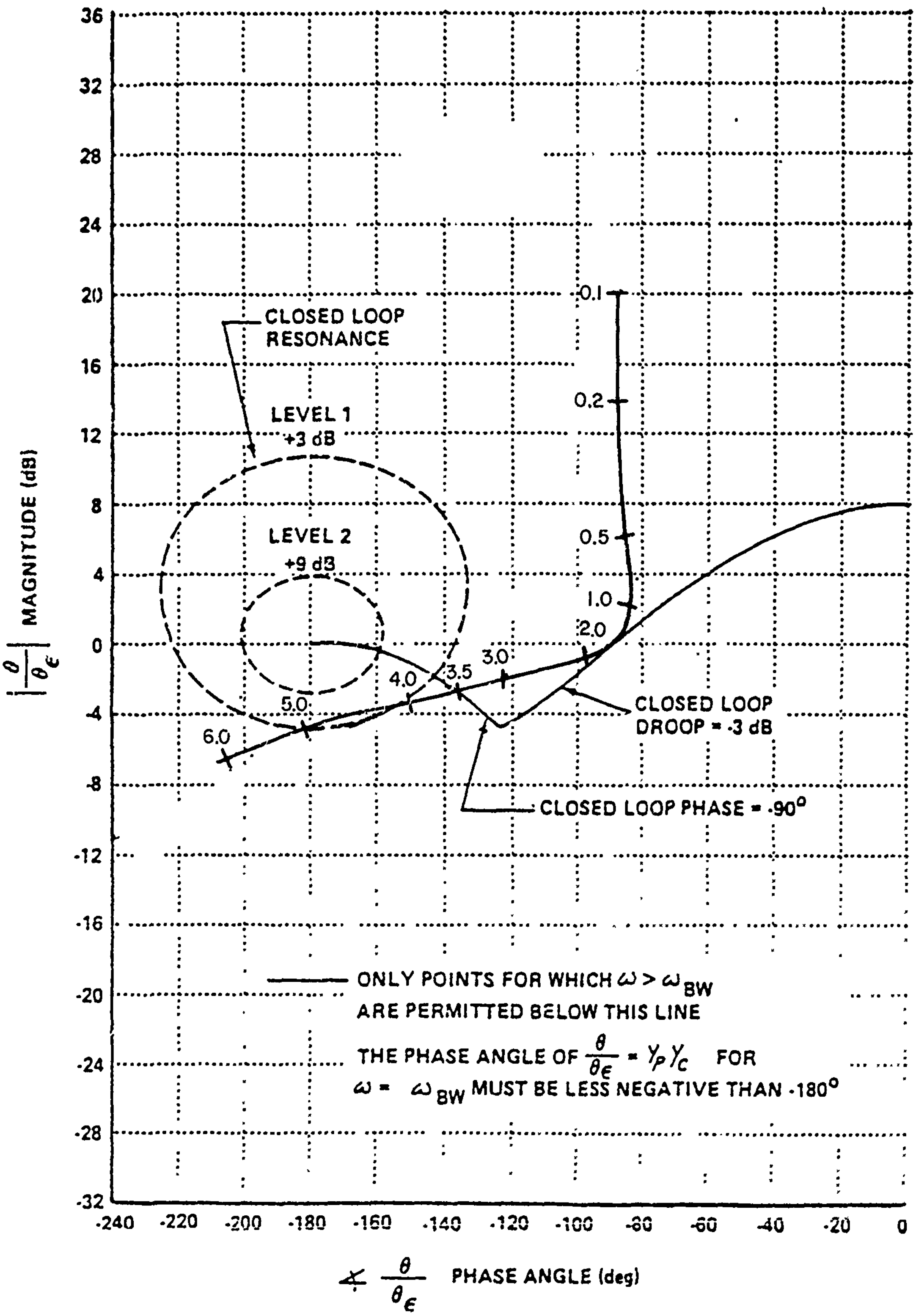


Figure 7. θ/θ_e for STI Case 3 With No Feel System (Approximates Neal-Smith [Ref. 8] Case 2D)

b. Neal-Smith Criteria

Because of the questions that arose with the modified Neal-Smith criteria from MIL-STD-1797, it was decided that the original criteria as developed in 1970 (Reference 8) should also be applied. These criteria differ in several ways: 1) assumed pilot time delay is 0.3 sec, rather than 0.25 sec; 2) the closed-loop bandwidth frequency is 3.0 rad/sec instead of 3.5 rad/sec; 3) pilot compensation resulting from the lead-lag is an important element in the criteria. Otherwise, application is identical to that described in Figure 5.

The Neal-Smith criteria, with the STI cases added, are shown in Figure 8. By this requirement, both Cases 11 and 3 are expected to be Level 1 (with HQRs of around 2 to 3); Case 8 is Level 2 (HQRs 5-5.5); and only Cases 2 and 5 are Level 3 (HQRs 7 to 10).

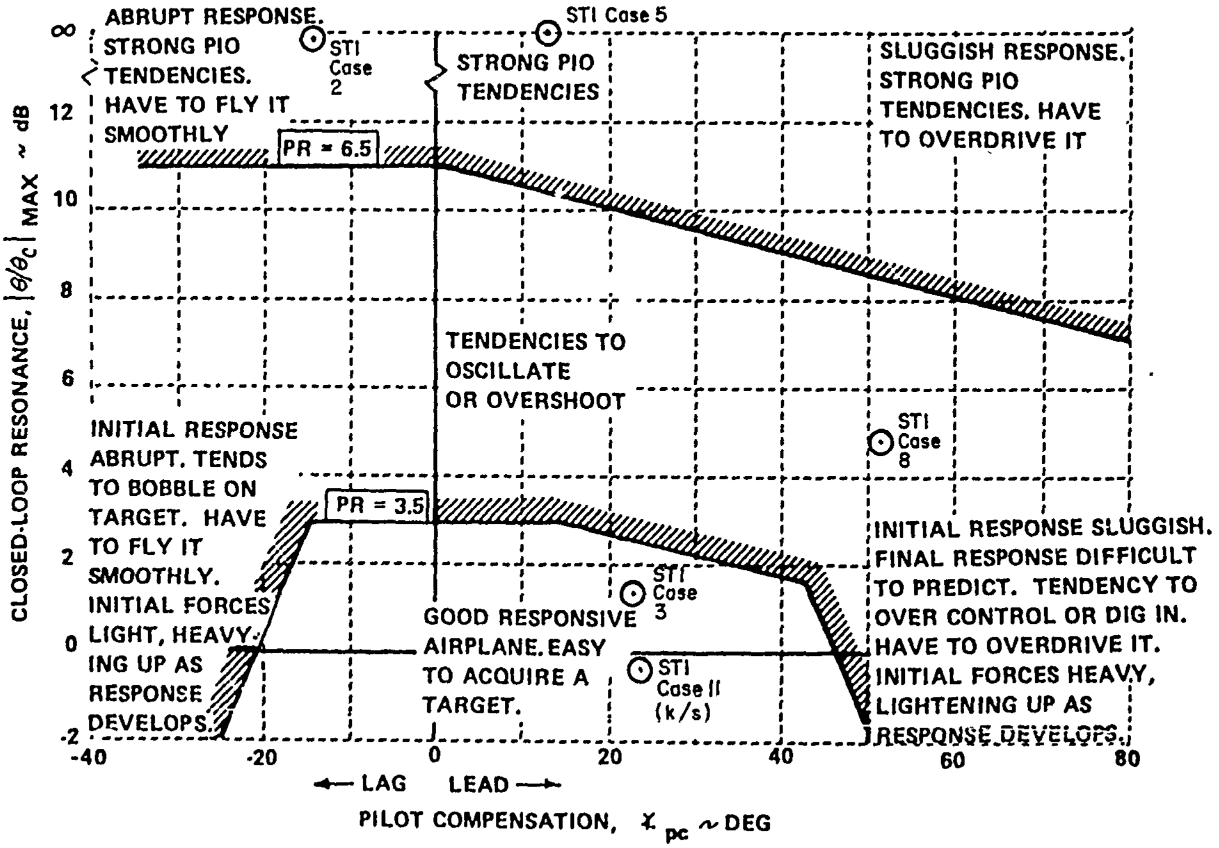


Figure 8. Primary Pitch Configurations Compared to Neal-Smith Criteria of Ref. 8

c. The Optimal Control Pilot Model

The optimal control model (OCM) of the human operator can be applied to the estimation of handling qualities in single- and multiple-axis operations. In addition to HQRs, however, the OCM also produces a prediction of the pilot's behavior and performance in the closed-loop task.

The optimal control model is based on the assumption that the pilot estimates the state of the aircraft and develops a control strategy that minimizes a performance index. Early work in this area was performed in 1970 (Reference 14), and models were developed that showed good agreement with actual test data. A detailed description of the OCM as it has been applied in this study is contained in Volume II of this report; the interest in this volume is in the application and interpretation of the output of the OCM.

For estimates of HQRs, the primary pitch configurations of Table 2 were entered into an IBM-PC-based implementation using Program CC (Reference 15). The forcing function command signal was modeled by a second-order Butterworth filter with a bandwidth of 2 rad/sec, and the rms of the commanded error was set at 1.09 deg. The OCM determines the minimum of a performance index J, which is a combination of the perceived error and control activity. Similar operations with optimal-control applications to the Reference 3 Dander data have shown a strong correlation between J and HQR (Reference 6). This is illustrated by Figure 9, taken from Reference 6.

From Figure 9, the general formula for HQR as a function of J_{task} results (where the "task" subscript refers to the overall cost function for single- and multi-axis tasks):

$$HQR = 7.7 + 3.7 \log_{10} J_{task}$$

Several modifications to this formula are necessary before it can be applied to other situations. Firstly, the "J_{task}" used here is actually normalized by the square of the rms error amplitude, σ_c^2. Secondly, the constant (7.7) includes in it a term related to the square of the forcing function noise bandwidth (for the data of Figure 9, the forcing function

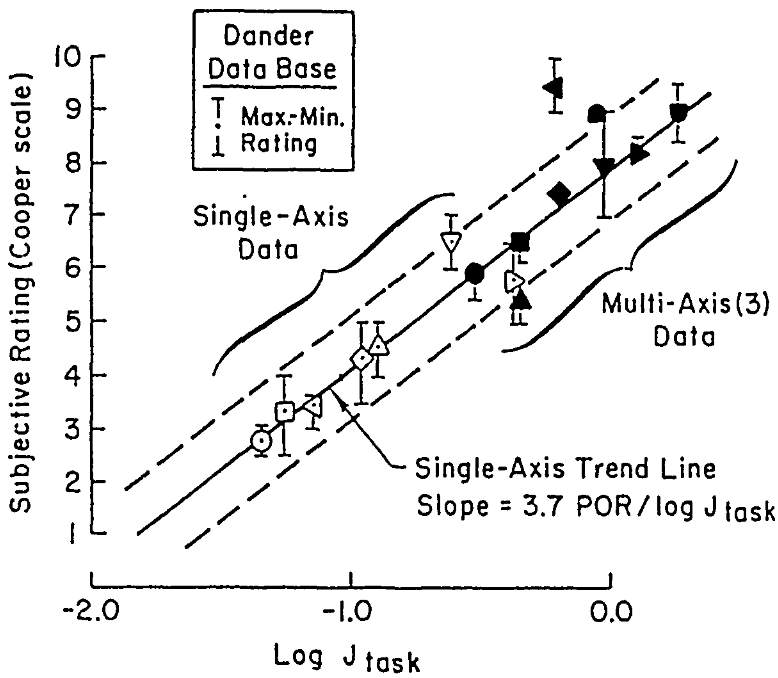


Figure 9. "Cost Function"/Rating Correlation for Dander (Ref. 3) Data; Figure Taken from Ref. 6

bandwidth was assumed to be 0.5 rad/sec in all axes). The actual equation for estimating HQRs is

$$\mathrm{HQR} = 5.5 + 3.7\ [\log_{10}(J/\sigma_c{}^2) - \log_{10}(\omega_w{}^2)]$$

or, in general,

$$\mathrm{HQR} = 5.5 + 3.7\ \log_{10}[J/(\sigma_c{}^2\ \omega_w{}^2)]$$

For the values of σ_c and ω_w assumed here (1.09 deg and 2 rad/sec, respectively), the specific pitch-axis equation for this experiment is:

$$\mathrm{HQR} = 2.9 + 3.7\ \log_{10}(J)$$

For the STI simulation cases, the values of J and estimated HQR and flying qualities Level are as follows:

STI Case	J	HQR	Level
11 (k/s)	0.529	1.9	1
3	0.635	2.2	1
8	0.874	2.7	1
	0.726	2.4	1
	0.924	2.8	1

Inspection of these Level estimates and comparison with other criteria previously presented suggests that the OCM is quite optimistic in its evaluation of the handling qualities of the configurations. Fortunately, unlike all of the other criteria, the OCM also produces an estimate of the pilot behavior in the form of a model of the human operator. This model can be evaluated here to gain insight into the operation of the OCM technique, and when the actual simulation test data are introduced, it can be compared with what the pilots really did. Three representative examples of the OCM output are chosen here to illustrate the successes and failures of the OCM, as it was applied in this study, as a predictive tool.**

The simplest example of the OCM's application is for the case where the controlled element is k/s (STI Case 11). The OCM generates an initial model of the pilot that is of very high order (10th-order transfer functions are common). Many of the terms in this high-order transfer function are exact or approximate pole-zero cancellations, while others can be lumped into an effective time delay. For the k/s case, the simple pilot model Y_p is given by

$$Y_p = \frac{29.4\ (0.54)(2.54)e^{-0.072s}}{(9.9)\ [0.71,\ 2.0]}$$

**It must be emphasized at this point that answers to many of the questions raised about the OCM techniques are known. The intent here is only to attempt to apply the OCM to a single, limited data base. The scope of this effort did not allow for an in-depth investigation of the characteristics of the OCM and development of solutions. Such an endeavor is clearly warranted.

The second-order pole corresponds to the driving noise (i.e., the OCM pilot generates an internal model of the driving noise). This model is of higher order than might be expected based on the classical crossover model (Reference 16), especially given the very simple controlled element; further reduction may be performed, if desired, by including the pole at 9.9 rad/sec into the time delay term and cancelling the zero at 2.54 rad/sec with the second-order pole. Such cancellations are generally not necessary, since it is the behavior around crossover that most interests us here.

Figure 10 shows the magnitude Bode plots of Y_c, Y_p, and Y_pY_c for the k/s example, along with the asymptotes of the magnitudes. The lead at 0.54 rad/sec serves to improve the crossover frequency (improving it from 1 rad/sec for the airplane alone to 3.4 rad/sec for the airplane plus pilot). The system does exhibit crossover characteristics at the crossover frequency, though the low-frequency dynamics are somewhat unusual.

The second example of the OCM application is for STI Case 3 (the best short-period configuration, Table 2). For this configuration, the approximate pilot model is

$$Y_p = \frac{0.12\ (0.28)(2.4)[0.80,\ 4.88]e^{-0.185s}}{(1.25)\ [0.71,\ 2.0]}$$

For this aircraft, the OCM pilot includes not only an internal model of the forcing function (the pole at [0.71, 2.0]), but a model that represents the inverse of the airplane. Thus the OCM pilot has generated a prediction of the controlled element. The resulting Bode plots are shown in Figure 11. The crossover frequency for this case is 2.6 rad/sec.

The final pitch example is for the worst airplane configuration (STI Case 5), with both low damping and high time delay. As with the previous case, the OCM pilot model represents the inverse of the airplane:

$$Y_p = \frac{0.069\ (0.20)(1.84)[0.15,\ 4.95]e^{-0.122s}}{(1.26)[0.72,\ 2.0]}$$

The resulting crossover frequency is extremely low (0.2 rad/sec, Figure 12). This is akin to the crossover-law situation for "crossover

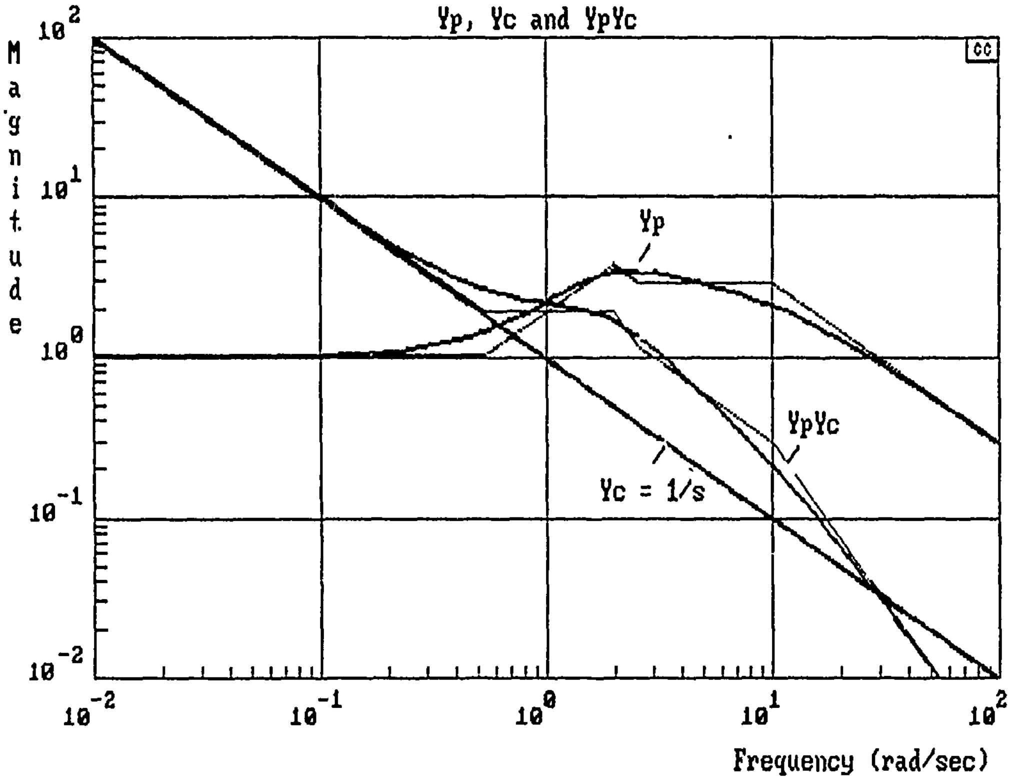


Figure 10. Example of OCM for Y_c=k/s (STI Case 11)

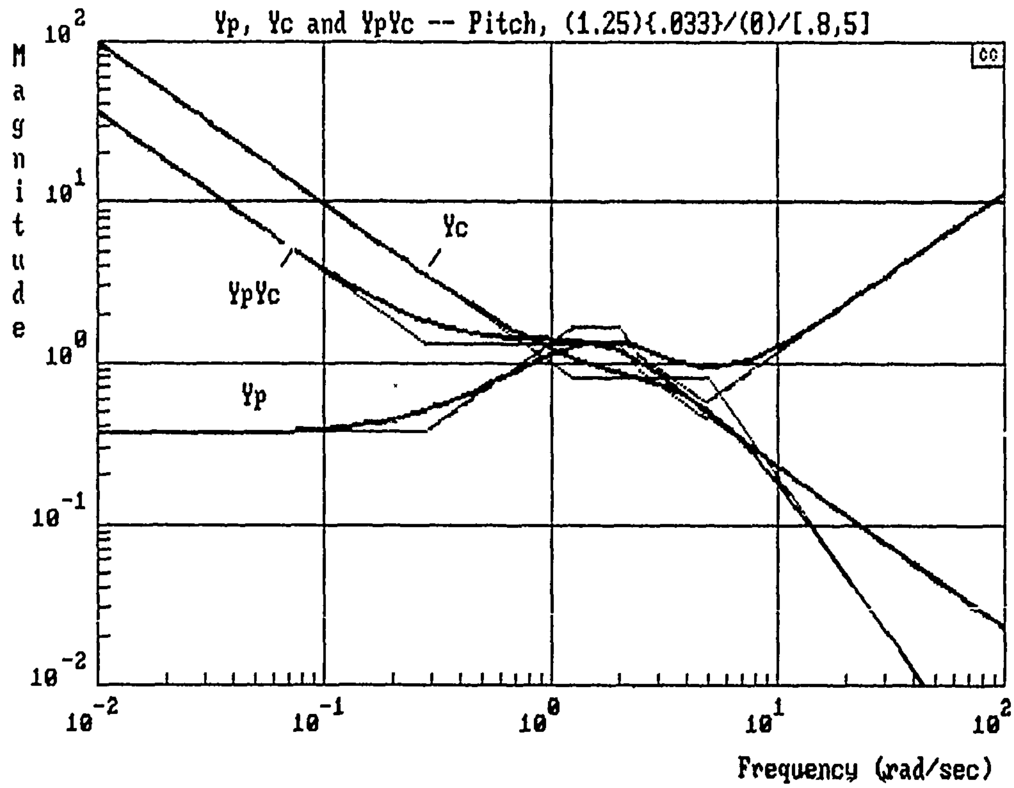


Figure 11. Example of OCM for STI Pitch Case 3

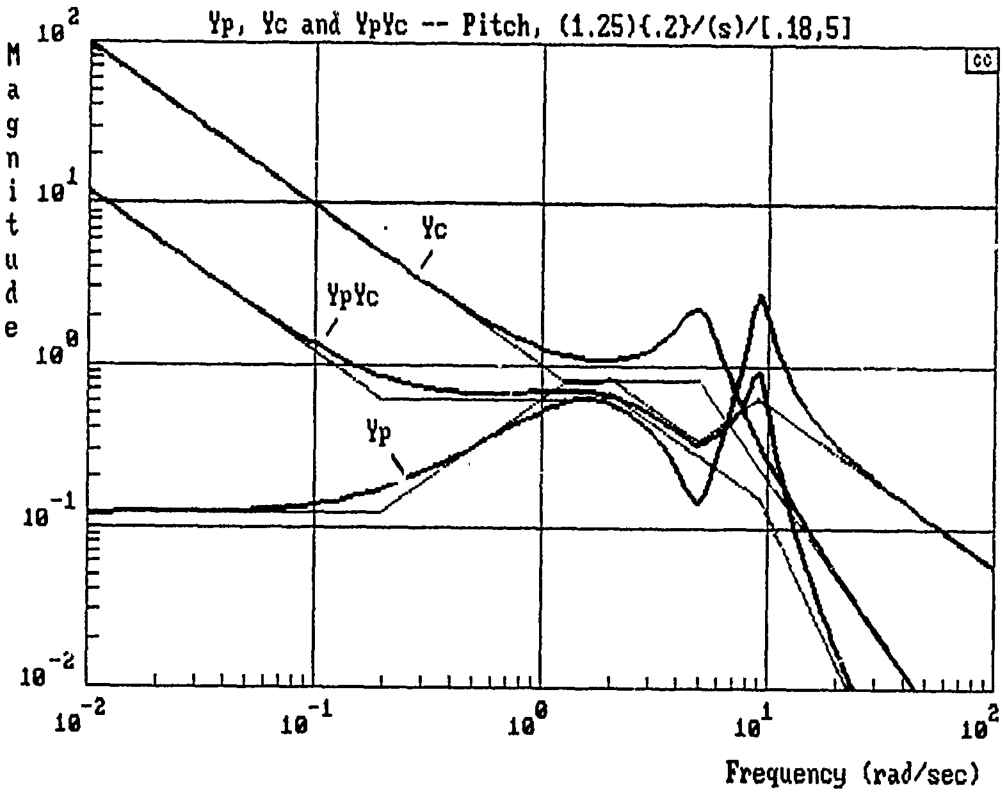


Figure 12. Example of OCM for STI Pitch Case 5

regression" (Reference 16): the combination of bad airplane and tough task have become too much to handle, and the pilot regresses to a crossover frequency below the input bandwidth frequency. The Bode plots of Figure 12 show that the OCM pilot model simply does not try to control this airplane. The resulting cost function actually does not reflect how badly the pilot is doing (J = 0.924, compared to, for example, 0.529 for k/s). Since J is a minimum on both error and control activity, this low value reflects a compensation for the high error by very low control activity. As a result, the estimated HQR for this case, 2.8, seems exceedingly optimistic. This case will be re-examined when the results of the piloted simulations are discussed.

d. Adjectival Descriptions for the Aircraft

The final method applied to estimate the handling qualities of the pitch configurations involved construction of a table of verbal descriptions for each case, . ing the aircraft-centered and pilot-centered

terminology of the Cooper-Harper pilot rating scale. For this method, an experienced handling qualities engineer was asked to qualitatively assess the expected handling qualities of the aircraft models by tabulating notable features in three categories: 1) aircraft characteristics (unusual damping, frequency, delay, etc.); 2) demands on the pilot (special compensation required as a result of the unusual aircraft characteristics, etc.); and 3) typical pilot comments (expected comments for such aircraft based on prior experiences). This method of estimation of handling qualities is typical of the processes involved in any initial assessment by a handling qualities engineer when evaluating a new design.

Table 3 shows the descriptions for the five primary pitch configurations. By relating the descriptions in this table to the HQR scale, a very rough estimate of HQR ranges was made (this was done by two separate evaluators; the numbers quoted here come from a relatively inexperienced engineer who was unfamiliar with the configurations but who was instructed to adhere closely to the structure and terminology of the Cooper-Harper scale). The resulting estimated HQRs and Levels are as follows:

STI Case	HQR Range	Level
11 (k/s)	2	1
3	2-2.5	1
8	4.5-5	2
2	6	2
5	7-8	3

2. Roll Criteria

a. Roll Response Requirements from MIL-STD-1797

The only criteria of interest here are the roll mode time constant and equivalent time delay criteria from MIL-STD-1797. The extremely simple models used for the roll configurations (Table 2) did not include any Dutch roll oscillations or other contaminating effects.

Figure 13 shows the requirements on T_R and τ_{e_p} from MIL-STD-1797, and the values of these parameters for the four primary roll configurations. Only STI Case J (k/s) is estimated to be Level 1; Case D is Level

TABLE 3. PILOT-CENTERED ADJECTIVAL DESCRIPTIONS FOR PITCH CONFIGURATIONS

STI CASE	$Y_{c\theta}$	AIRCRAFT CHARACTERISTICS	DEMANDS ON THE PILOT	TYPICAL PILOT COMMENTS
11	k/s	• Ideal	• No special compensation • Insensitive to gain changes	• Responsive • Good precision
3	$\frac{20(1.25)e^{-0.033s}}{(0)[0.8,\ 5.0]}$	• Good	• No special compensation • May choose to lag near $1/T_{\theta_2}$ to remove shelf • Very insensitive to pilot gain	• Good response • No problems with precision • Possibly slight tendency to bobble on target
8	$\frac{20(1.25)e^{-0.2s}}{(0)[0.8,\ 5.0]}$	• High time delay	• Lead to compensate for delays • Low crossover is likely	• Sluggish initial response • Tendency to bobble • Lack of precision
2	$\frac{20(1.25)e^{-0.033s}}{(0)[0.2,\ 5.0]}$	• Low damping	• Lag at low frequency to improve gain margin • Lead at high frequency to improve phase margin • Limitation on closed-loop gain, highly sensitive to gain changes	• Oscillatory, abrupt • High pitch sensitivity • Strong overshoot tendency • Can't tighten up without PIOs
5	$\frac{20(1.25)e^{-0.2s}}{(0)[0.18,\ 5.0]}$	• Low damping • High time delay	• Same as Case 5 • Low crossover frequency	• Very PIO-prone • Sluggish initially, then oscillates • Have to temper inputs

LEVEL	MAXIMUM ROLL MODE TIME CONSTANT, T_R(sec)	MAXIMUM EQUIVALENT TIME DELAY, τ_{ep}(sec)
1	1.0	0.10
2	1.4	0.20
3	1.0	0.25

a. Requirements

	T_R(sec)		τ_{ep}(sec)	
CASE	VALUE	LEVEL	VALUE	LEVEL
J	~ 0	1	0.061	1
B	2.0	3	0.128	2
G	2.0	3	0.261	>3
D	0.25	1	0.128	2

b. Values for Configurations (STI Cases)

Figure 13. Comparison of Primary Roll Configurations with Relevant Requirements from MIL-STD-1797

2 due to excessive time delay; Case B is Level 2 due to delay and Level 3 due to the low roll mode; and Case G should be Level 3 or worse for both criteria.

b. Criteria from LATHOS Experiments

The flight experiments of Reference 9 (referred to as LATHOS, for LAteral Higher Order Systems) were used by the authors of that reference to develop a time-domain-based requirement on effective time delay and roll mode time constant ("effective" rather than "equivalent" to indicate time-domain rather than frequency-domain definitions). Figure 14 shows the requirements from Reference 9. From Figure 14 rough estimates of both flying qualities Level and HQR may be made.

All four of the roll configurations lie in the Level 3 region of Figure 14, including k/s (STI Case J). The elimination of cases with combinations of low time delay and high roll damping are due to roll ratcheting experienced during the flight tests. There was no reason to expect that ratcheting would occur in the current fixed- and moving-base simulations; on the other hand, the interest here is in application of the criteria as they are drawn in Figure 14, and from this figure, all cases should be Level 3 with estimated HQRs ranging from about 7 (for Cases D and J) to 10 (for Cases B and G).

c. Optimal Control Model Criteria

The general formula for HQR as a function of cost function, J, was given for the pitch situation; in roll, with a forcing function bandwidth of 2 rad/sec and input error rms amplitude of 6.73 deg,

$$HQR = -2.9 + 3.7 \log_{10}(J)$$

Computed values of J and resulting estimates of HQR and Level are as follows:

STI Case	J	HQR	Level
J (k/s)	20.1	1.9	1
B	122.2	4.8	2
G	252.0	6.0	2
D	37.1	2.9	1

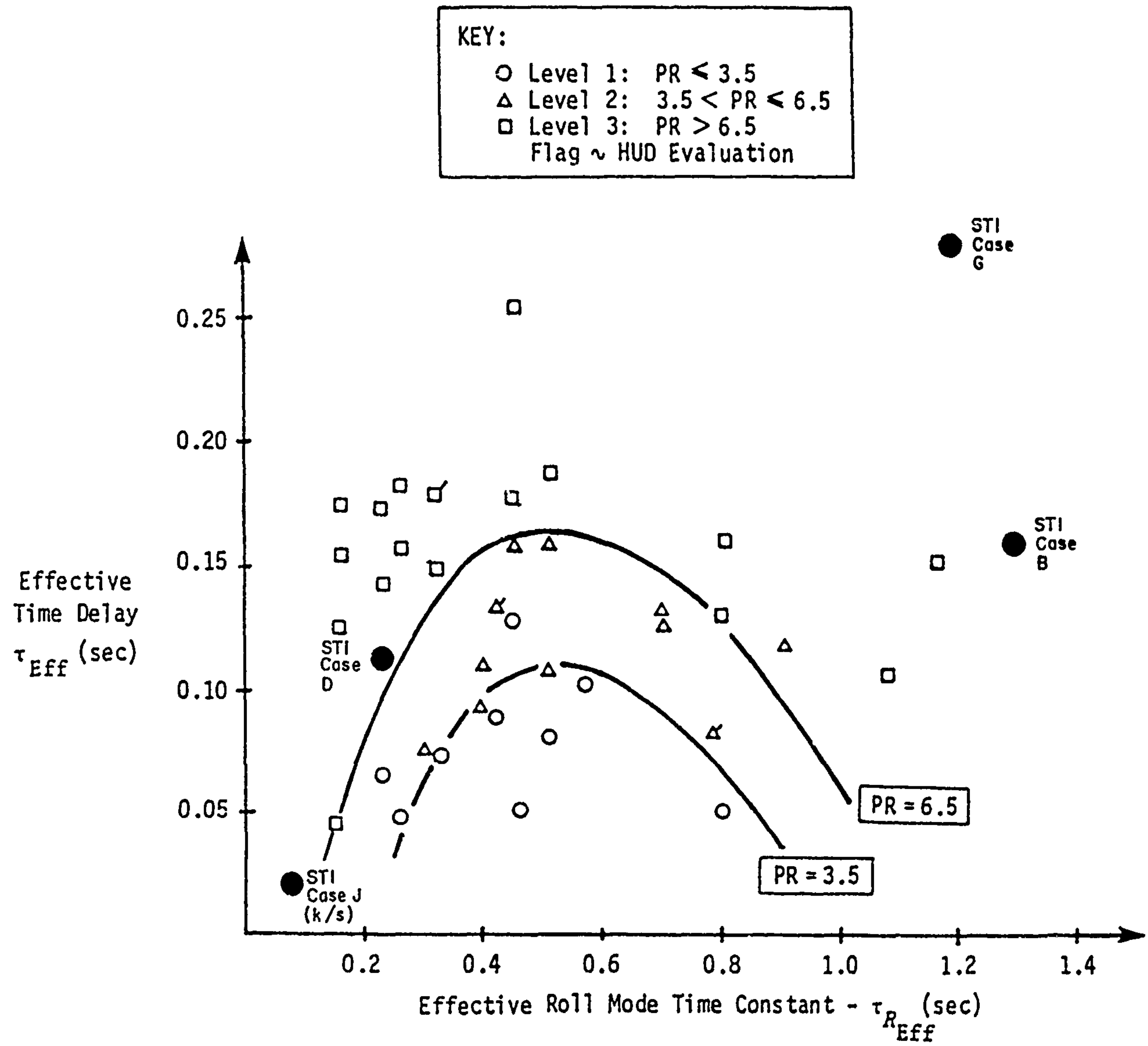


Figure 14. Primary Roll Configurations Compared to LATHOS Criteria of Ref. 9

Since the controlled element and forcing function bandwidths are identical for pitch Case 11 and roll Case J (i.e., k/s), the OCM pilot models were also identical. Figure 15 shows the Bode plots and pilot model from the OCM for roll Case G (the worst airplane). The OCM supplies a lead at 1.2 rad/sec to improve the crossover frequency to 2.1 rad/sec. (The low-damped second-order mode at 8.2 rad/sec can be considered a part of an overall effective time delay.) Unlike the pitch cases, the estimated HQRs listed above do not seem especially unreasonable, and the pilot model of Figure 15 closely follows the crossover law (Reference 16) expectations. This configuration will be re-examined when the actual simulation results are analyzed.

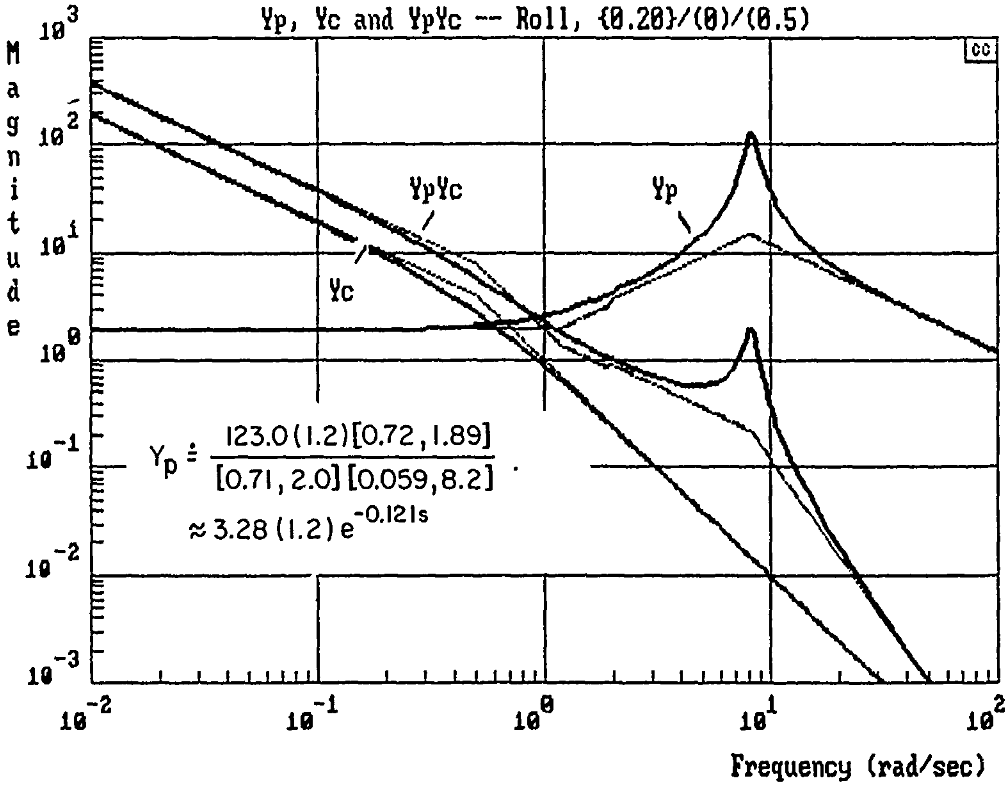


Figure 15. Example of OCM Model for STI Roll Case G

d. Adjectival Descriptions for the Aircraft

This method of qualitatively judging the expected handling qualities of the aircraft configurations was described for the pitch cases.

The descriptions are listed in Table 4. Estimated HQRs and Levels were as follows:

STI Case	HQR	Level
J (k/s)	2	1
B	5-6	2
G	6	2
D	2	1

3. Combined-Axis Criteria

a. OCM

The single-axis costs for the pitch and roll cases vary as a function of attentional fraction f_i (e.g., Reference 15), where f_i ranges from 0 (no attention) to 1 (full attention) and the subscript i refers to the axis under consideration. Application of the OCM to two (or more) axes involves determining the dependence of cost J on the attentional fractions by computing J for the full range of f_i for each axis of control, and then optimizing the overall multi-axis J over the f_i's. This optimizing process is quite involved, and a much simpler approach has been applied here. The single-axis J's were computed for varying values of f_i and then the final optimization was computed by hand. This final optimization uses an empirical relationship (Reference 15):

$$J_i/\sigma_{c_i}^{2} = a_i/f_i + b_i \text{ for } i = 1,\ldots,N_{axis}$$

This empirical relationship was derived from the experimental data generated by Dander (Reference 3) and holds for a range of f_i varying from $0.5 < f_i < 1.0$ to as low as $0.1 < f_i < 1.0$, depending upon the amount of lead required by the operator. Each single-axis problem was solved for enough values of f_i to be able to estimate the a_i and b_i coefficients and to determine the range of validity.

TABLE 4. PILOT-CENTERED ADJECTIVAL DESCRIPTIONS FOR ROLL CONFIGURATIONS

STI CASE	$Y_{c\phi}$	AIRCRAFT CHARACTERISTICS	DEMANDS ON THE PILOT	TYPICAL PILOT COMMENTS
J	k/s	• Ideal	• No special compensation	• Very responsive • Good precision
D	$\frac{4e^{-0.067s}}{(0)(4)}$	• Good	• No compensation • Very insensitive to gain changes	• Good response overall
B	$\frac{0.5e^{-0.067s}}{(0)(0.5)}$	• Very low roll damping	• Lead near $1/T_R$ • Relatively insensitive to gain changes	• Sluggish initially • Poor damping • Requires pulse inputs
G	$\frac{0.5e^{-0.2s}}{(0)(0.5)}$	• High time delay • Very low roll damping	• Lead near $1/T_R$ • Very sensitive to pilot lead and gain changes	• No precision • Bobbles, wallows, sluggish • Hard to stop • Very PIO-prone

The multi-axis optimization problem is to minimize with respect to the f_i's, subject to the constraint that the f_i's sum to 1. For the two-axis case, this problem is solved using standard Lagrangian/Hamiltonian techniques, i.e.,

$$1/f_1 = 1 + \sqrt{a_2/a_1}$$

$$1/f_2 = 1 + \sqrt{a_1/a_2}$$

A final check was always made to assure that the f_i's were within the range of validity of the approximations used to obtain the a_i's.

The empirical formulas for J, and resulting f_i's and estimated HQRs, are listed in Table 5 for the primary configurations. STI Cases 2 and 5, for which the single-axis OCM estimates were optimistic, have not been included here. The final estimates of HQR are based on the general equation for HQR as a function of J,

$$HQR = 5.5 + 3.7 \log_{10}[J/(\sigma_c^2 \, \omega_w^2)]$$

b. Product Rule Applications

The Product Rule (or Product Method) is a purely empirical formula for combining single-axis HQRs into an overall multi-axis HQR. The method was developed in Reference 7 and is based primarily on the Dander experiment data of Reference 3.

Pilot ratings for 2- and 3-axis tasks were compared with the individual ratings for the corresponding single-axis equivalents to determine a general equation,

$$R_m = 10 + \frac{1}{(-8.3)^{(m-1)}} \prod^{m} (R_i - 10)$$

Data correlations for HQRs from several sources show this to be quite effective (i.e., Figure 16, from Reference 7).

The Product Rule is applied here for those single-axis criteria where actual estimates of HQR (or HQR range) were possible, with the exception of the OCM method, which separately allows for multi-axis ratings. It is

TABLE 5. MULTI-AXIS OCM ESTIMATES OF HQR

a. Empirical Formulas for J/σ_c^2:

$$\frac{J}{\sigma_c^2} = \frac{a}{f} + b$$

CASE	a	b	Range of Validity
11	0.067	0.43	$f \geq 0.24$
3	0.048	0.48	$f \geq 0.25$
8	0.040	0.696	$f \geq 0.30$
J	0.067	0.43	$f \geq 0.25$
B	1.44	1.4	$f \geq 0.30$
G	4.25	1.8	$f \geq 0.50$
D	0.075	0.775	$f \geq 0.35$

b. Computed Attentional Fractions and Estimated HQRs:

$$1/f_1 = 1 + \sqrt{a_2/a_1},\quad 1/f_2 = 1 + \sqrt{a_1/a_2}$$

$$\frac{J_{task}}{\sigma_c^2} = \left(\frac{a_1}{f_1} + b_1\right) + \left(\frac{a_2}{f_2} + b_2\right)$$

$$HQR = 5.5 + 3.7 \log_{10} \left(\frac{J_{task}}{\omega_w^2\ \sigma_c^2}\right)$$

PITCH CASE	ROLL CASE: J	B	G	D
11	$f_1 = .5$ $f_2 = .5$ HQR = 3.5	$f_1 = .18$ $f_2 = .82$ HQR = 5.5	$f_1 = .11$ $f_2 = .89$ HQR = 6.5	$f_1 = .49$ $f_2 = .51$ HQR = 3.9
3	$f_1 = .46$ $f_2 = .54$ HQR = 3.5	$f_1 = .15$ $f_2 = .85$ HQR = 5.4	$f_1 = .10$ $f_2 = .90$ HQR = 6.5	$f_1 = .44$ $f_2 = .56$ HQR = 3.9
8	$f_1 = .44$ $f_2 = .56$ HQR = 3.7	$f_1 = .14$ $f_2 = .86$ HQR = 5.5	$f_1 = .09$ $f_2 = .91$ HQR = 6.5	$f_1 = .42$ $f_2 = .58$ HQR = 4.1

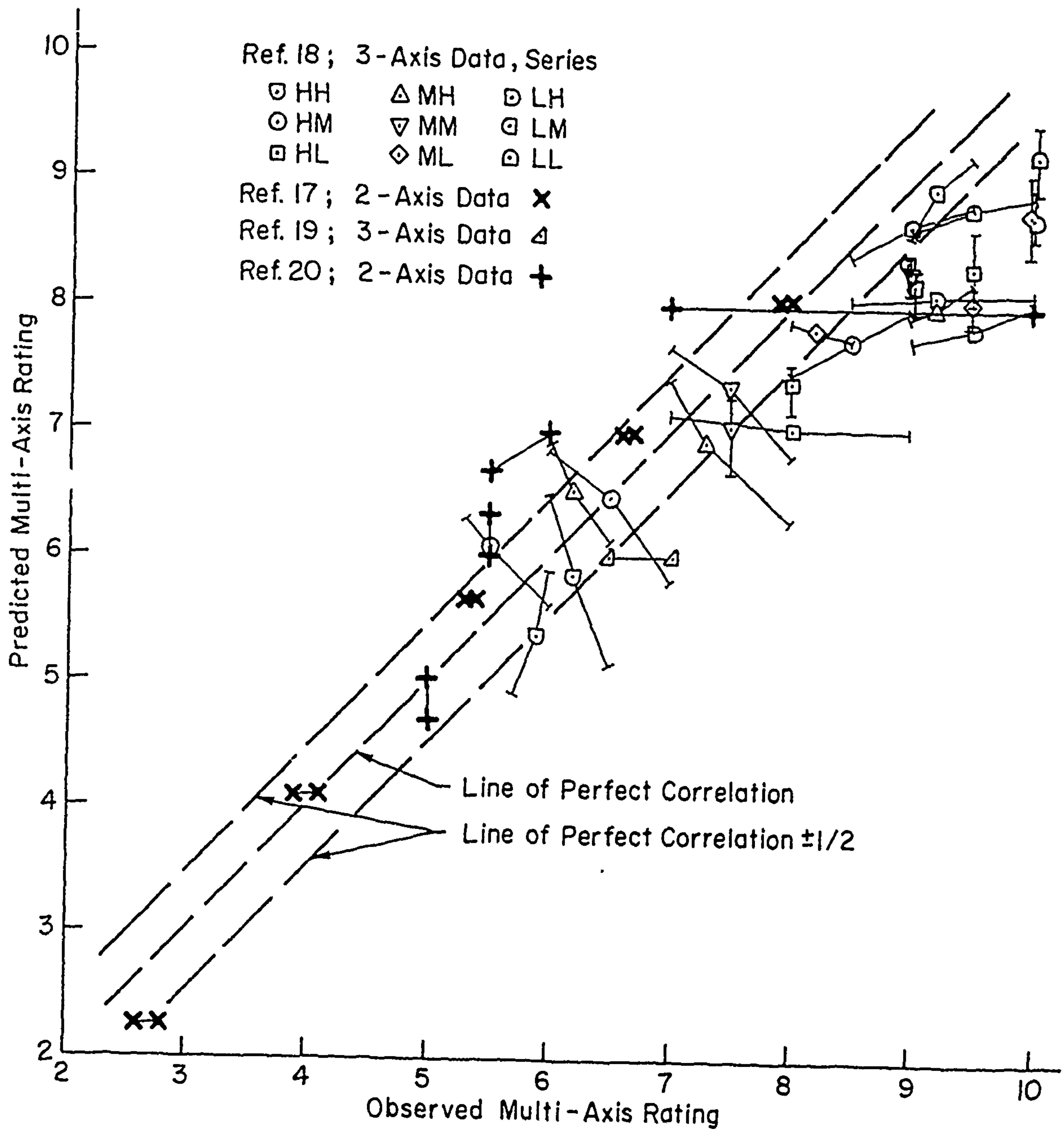


Figure 16. Product Rule Correlations (from Ref. 7; Reference Numbers are for Ref. 7)

logical to combine only those single-axis criteria that are similar in nature -- as an experienced flying qualities engineer would be expected to do -- and not consider inconsistent combinations. The following criteria produced estimates of HQRs or ranges of HQRs:

Pitch -- Bandwidth, Neal-Smith, Descriptors

Roll -- LATHOS requirements, Descriptors

If the engineer had quantitative criteria available, such as the bandwidth and LATHOS requirements, a multiple-axis combination of these criteria is reasonable. On the other hand, combinations of, for example, bandwidth with the qualitative descriptors is not so reasonable. The multi-axis combinations applied here are: 1) bandwidth + LATHOS; 2) Neal-Smith + LATHOS; and 3) descriptors (pitch and roll). Table 6 summarizes all of the relevant single-axis Level and HQR estimates described previously (including OCM for completeness). From this table and the specified Product Rule applications, the estimates for pitch/roll HQRs for the five pitch and four roll configurations are tabulated in Table 7.

A review of Table 7 indicates extremely pessimistic estimates of handling qualities, especially for the first two criteria combinations. This is due primarily to the very stringent nature of the LATHOS roll response limits of Figure 14, where two of the roll cases (D and J) are too responsive and the other two (B and G) are much too sluggish, compared to the LATHOS data. This table suggests that almost all of the two-axis combinations will be unflyable.

A preliminary evaluation of the success or failure of the estimates in Tables 5, 6, and 7 is presented in the next section of this report, with final evaluation when the moving-base simulation results are reviewed.

D. CROSSOVER MODEL CONSIDERATIONS

Structural models of the human operator can be constructed assuming compensatory control of the primary pitch and roll configurations by applying the crossover models of Reference 16. From these models, rough

TABLE 6. SUMMARY OF SINGLE-AXIS FLYING QUALITY LEVEL ESTIMATES

a. Pitch

					BANDWIDTH		NEAL-SMITH		OCM		DESCRIPTORS	
CASE	CAP	$\omega_{sp}T_{\theta_2}$	TPR	PILOT-IN THE-LOOP	LEVEL	$\hat{R}_\theta$	LEVEL	$\hat{R}_\theta$	LEVEL	$\hat{R}_\theta$	LEVEL	$\hat{R}_\theta$
11	N/A	N/A	1	1	1	2-2.5	1	2-2.5	1	1.9	1	2
3	2	2	1	2	2	5-5.5	1	2.5-3	1	2.2	1	2-2.5
8	>3	>3	>3	3	3	8-9	2	5-5.5	1	2.7	2	4.5-5
2	2+	2+	2	3	3	6.5-7	3	7-10	1	2.4	2	6
5	>3+	>3+	>3+	3	>3	9-10	3	7-10	1	2.8	3	7-8

b. Roll

		LATHOS		OCM		DESCRIPTORS	
CASE	MIL-STD-1797 (T_R, τ_{ep})	LEVEL	$\hat{R}_\phi$	LEVEL	$\hat{R}_\phi$	LEVEL	$\hat{R}_\phi$
J	1	3	7	1	1.9	1	2
B	3+	>3	10	2	4.8	2	5-6
G	>3+	>3	10	2	6.0	2	6
D	2	3	7	1	2.9	1	2

Note: 1) A plus sign (+) indicates Level 2 or worse by more than 1 requirement;
2) $\hat{R}_\theta$, $\hat{R}_\phi$ indicate estimated HQRs.

TABLE 7. APPLICATION OF PRODUCT RULE TO PITCH/ROLL CASES

HQRs Are: Bandwidth + LATHOS; Neal-Smith + LATHOS; Descriptors (Pitch + Roll)

	ROLL CASE			
PITCH CASE	J	B	G	D
11	7.1-7.3; 7.1-7.3;2.3	10;10; 5.2-6.1	10;10; 5.2-6.1	7.1-7.3; 7.1-7.3;2.3
3	8.2-8.4;7.3-7.5;2.3-2.8	10;10; 5.2-6.4	10;10; 5.2-6.4	8.2-8.4;7.3-7.5;2.3-2.8
8	9.3-9.6;8.2-8.4;4.7-5.2	10;10; 6.7-7.6	10;10; 7.3-7.6	9.3-9.6;8.2-8.4;4.7-5.2
2,	8.7-8.9;8.9-10;6.1	10;10; 7.6-8.1	10;10; 8.1	8.7-8.9;8.9-10;6.1
5	9.6-10;8.9-10;7.1-8.1	10;10; 8.2-9.0	10;10; 9.0	9.6-10;8.9-10;7.1-8-1

estimates of HQRs can be made for a few of the configurations using established functions for rating decrements due to required pilot lead, gain compensation, etc. Such pilot models are especially insightful for analyzing the simulation results, as will be shown in other sections of this report. The following illustrates the expected pilot-vehicle characteristics for several example pitch and roll cases. It is not possible to estimate HQRs for all of the cases, however, since, as will be shown here, the pilot is required (at least for the pitch cases) to generate a net lag near the crossover frequency, and empirical relations for HQR due to such lag generation are not available. This is an area deserving of further analytical and experimental study, and, while the data presented in this report can serve as a foundation, it was not the purpose of this effort to develop pilot rating functionals for pilot lag. Much more data is needed for such an endeavor.

The fundamental precept of the crossover model is that the pilot, when faced with a continuous, compensatory tracking situation with the goal of minimizing displayed errors, will operate such that the pilot-vehicle effective transfer function, Y_pY_c, approximates k/s near the system crossover frequency (frequency for unity linear -- zero dB -- forward loop gain). Such a characteristic is both necessary for adequate closed-loop stability, and optimal in terms of reduction of system error (as elaborated in both Volume II and Reference 16).

The case of control when the plant is k/s (Pitch Case 11 and Roll Case J) is therefore not especially challenging to interpret: the crossover model states that the pilot will generate an overall time delay of around 0.2-0.3 sec (depending on the forcing function bandwidth), and perhaps some low-frequency integration to improve steady-state errors. In addition, of course, other higher-order effects related to the pilot's neuromuscular response, etc., will occur, and, in the case of the simulations conducted for this study, a slight lead will be necessary to compensate for the feel system delays.

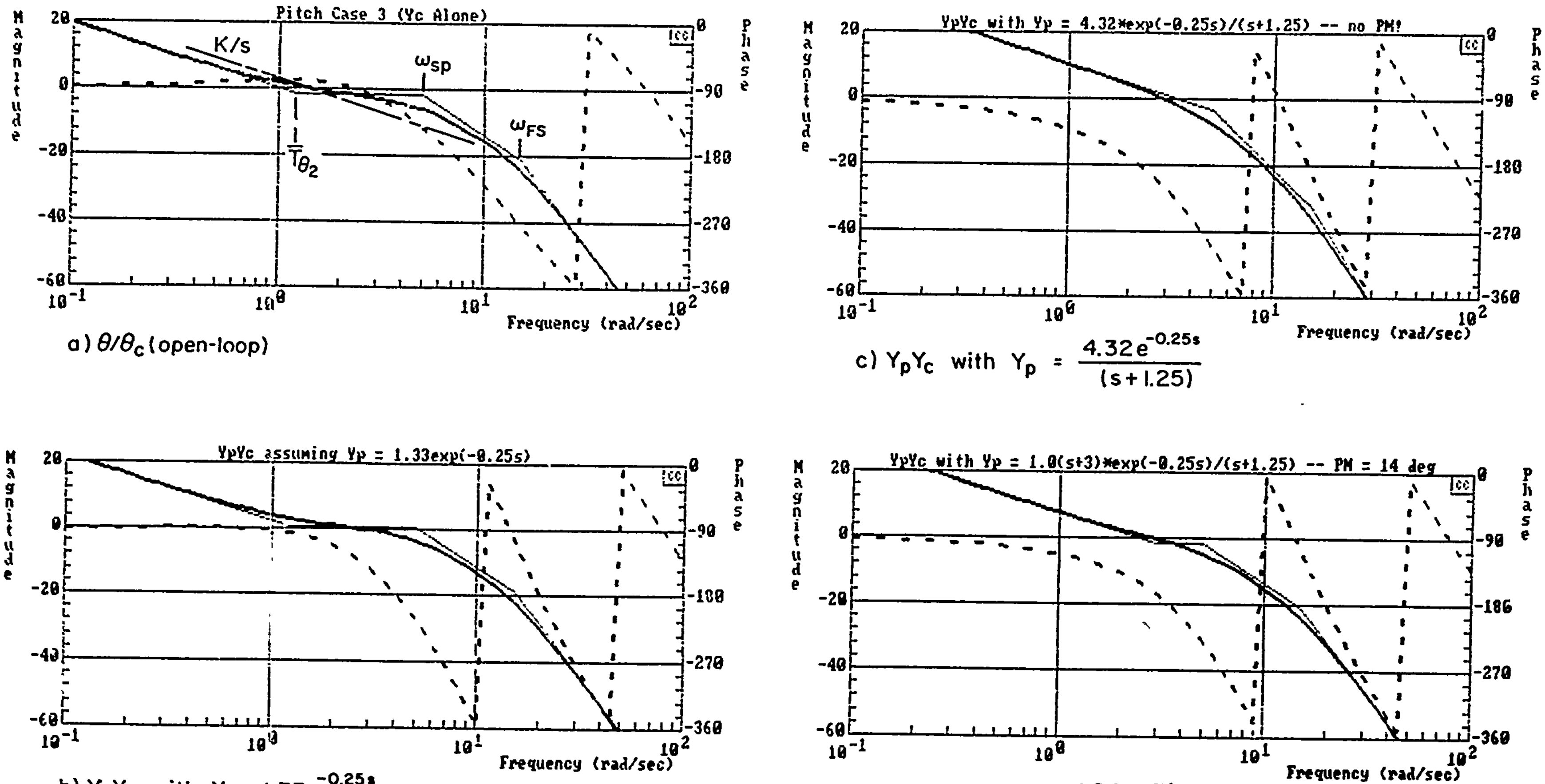
The more interesting models, for application of the crossover model and, more significantly, for interpretation of the simulation results, are the airplane-like cases, and especially the low-damped, high-delay

case (STI pitch Case 5). As a baseline, Case 3, with a relatively large frequency separation between $1/T_{\theta_2}$ and the short-period mode, but with otherwise good dynamics, will be examined first.

The Bode plot of pitch attitude (normalized to give $\theta_{SS} = 1$) for Case 3 is shown in Figure 17a. This case is k/s-like at low frequencies (below the break frequency for $1/T_{\theta_2}$), with the very apparent shelf between $1/T_{\theta_2}$ and the short-period producing a flattening of the amplitude ratio to something less than k/s (i.e., less than -20 dB per decade). The combination of feel system dynamics (at 15 rad/sec) and added time delay of 0.033 sec produces a large roll-off in magnitude and phase at high frequencies.

For an assumed pilot time delay of 0.25 sec (a value that may be somewhat conservative based on the rules of Reference 16, but which will serve our purposes) and a gain of 1.33, a crossover frequency of 3 rad/sec is achieved (Figure 17b) with ample phase margin. (A crossover frequency of 3 rad/sec was chosen for this example based on the reference input noise bandwidth of 2 rad/sec used for the OCM calculations; the pilot will certainly be able to achieve a crossover above the input bandwidth, and possibly greater than 3 rad/sec.) While a reasonable crossover is attained with a reasonable phase margin, the desired k/s-like shape has not been achieved. It is clear from Figure 17b that the region of k/s-like behavior around crossover can be greatly extended if lag is generated near the frequency of the attitude zero, 1.25 rad/sec. Such a situation is shown in Figure 17c: a crossover frequency of 3 rad/sec is maintained and the k/s region is more extensive, but at the expense of all available phase margin. The actual closed-loop dynamics cannot be achieved without incurring an instability, so clearly this is not a reasonable model of the pilot-plus-airplane system.

With some high-frequency lead generation, the phase margin can be raised near the crossover frequency and a stable system can be obtained. Figure 17d shows the system with a lead at 3 rad/sec; a lead at a higher frequency will not increase the phase sufficiently at the crossover frequency, and a lead at lower frequencies diminishes the positive effects of the added lag. The resulting pilot is predominately a <u>lag</u> generator near



a) θ/θ_c (open-loop)

c) Y_pY_c with $Y_p = \frac{4.32e^{-0.25s}}{(s+1.25)}$

b) Y_pY_c with $Y_p = 1.33e^{-0.25s}$

d) Y_pY_c with $Y_p = \frac{1.0(s+3)}{(s+1.25)}e^{-0.25s}$

Figure 17. Crossover Model for STI Pitch Case 3

crossover -- a dynamic situation for which little experimental pilot describing function data exists, as evidenced by a lack of information in Reference 16 on anticipated effects of lag generation on HQRs.

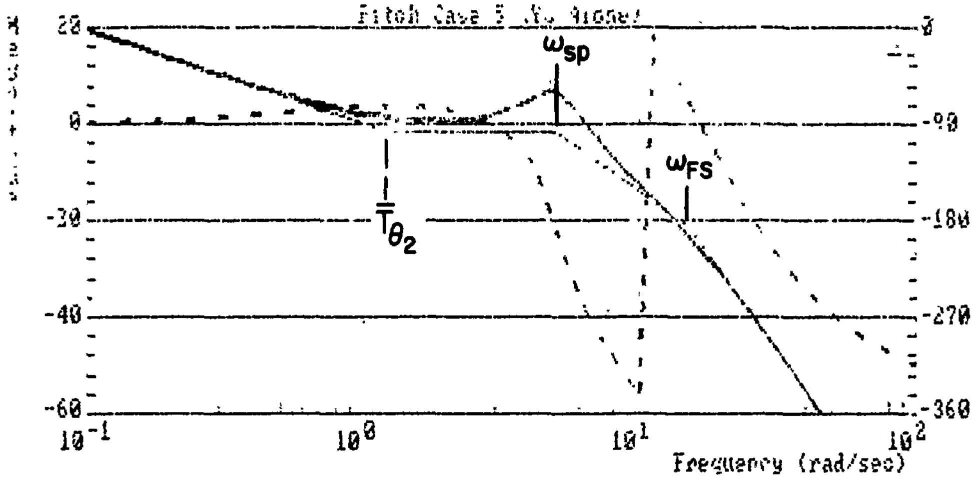
It must be noted that considerable data are available for the situation where the pilot is required to generate lag; control of a pure gain system -- i.e., $Y_c = k$ -- is the best example. Attitude command control systems are further examples for real aircraft, and recent work on handling qualities requirements for helicopters with attitude command systems (Reference 17) have not shown any significant problems with piloted control. For such systems, however, the lag generated by the pilot can be at very low frequencies, while the aircraft models examined here require lag generation near crossover -- a situation for which no pilot describing functions have been recorded before this study.

On the other hand, such systems are not altogether unfamiliar to the control systems designer, who will recognize the tendency for such shelf-like attitude responses to exhibit closed-loop droop at mid-frequencies (corresponding to mid-term errors in the time domain). If, for example, the short-period frequency were lower, the shelf would be reduced somewhat and the uncompensated system would look more k/s-like near the crossover frequency. It is, in fact, this mid-frequency shelf that creates some of the problems in applying pitch criteria such as the Neal-Smith analysis (where mid-frequency closed-loop droop is outlawed) and bandwidth (where the shelf causes this case to be gain-margin-limited, Reference 2).

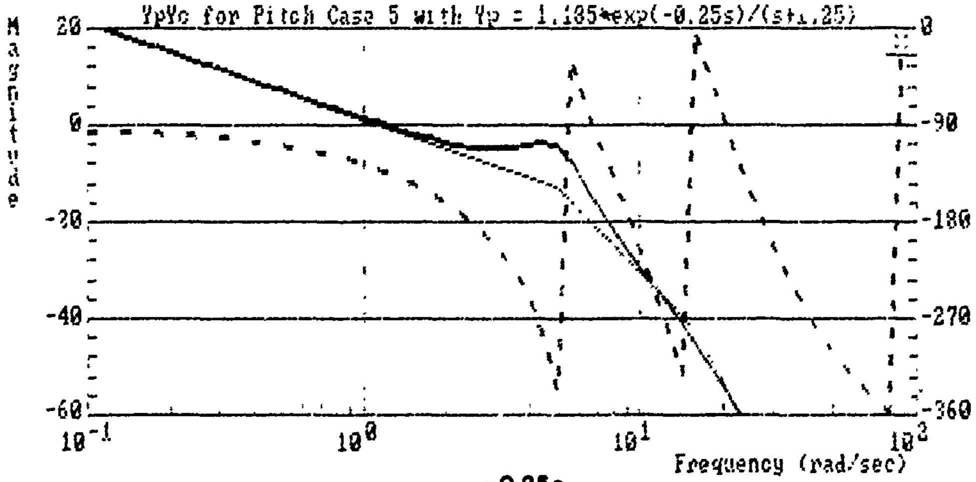
For the low-damped, high-time-delay case, the shelf at mid frequencies still exists in the attitude response, and in fact is heightened by the peaking in amplitude due to the low damping ratio, Figure 18a. With a representative time delay of 0.25 sec, it is almost impossible to get a reasonable crossover frequency without incurring a closed-loop oscillation resulting from the short-period mode. In this case, the best overall crossover response is placement of a lag near $1/T_{\theta_2}$, with no corresponding lead at higher frequencies, since such a lead will simply cause the short-period amplitude ratio to peak even more. For a gain margin of 3 dB on the short-period oscillation, the highest crossover frequency achievable, without some higher-order dynamics, is about 1.2 rad/sec, as shown in

Figure 18b. For the assumed input forcing function bandwidth of 2 rad/sec, this case is expected to exhibit characteristics of "crossover regression" (Reference 16): the pilot, resigned to the fact that the closed-loop task cannot be performed as required, will regress and attempt to control only lower-frequency components of the forcing function. This hypothesis for the control of Case 5 will be investigated in both the fixed-base and moving-base simulation programs.

All of the roll configurations are more classical in form (Table 2), requiring only placement of lead to compensate for the presence of less-than-ideal roll mode damping. Such lead will also naturally help improve phase margin in the presence of large time delays.



a) θ/θ_c (open-loop)



b) $Y_p Y_c$ with $Y_p = \dfrac{1.185e^{-0.25s}}{(s+1.25)}$

Figure 18. Crossover Model for STI Pitch Case 5

SECTION IV

PRELIMINARY EVALUATION OF ESTIMATES FROM FIXED-BASE SIMULATION

A. BACKGROUND

A fixed-base simulation was conducted prior to initiating the moving-base simulation program. This simulation, performed at Systems Technology, Inc., investigated minimum flying qualities situations for one and two axes (pitch alone, roll alone, and combined pitch and roll). This section of the report reviews the more significant results of the simulation, especially as they were to impact the design of the moving-base study. A complete description of the simulation and summary of the results is given in Appendix A. The primary concerns in this section are: 1) validity of the simulation design and scenarios; 2) an initial assessment of all single-axis and multi-axis criteria described in Section III; 3) a brief investigation into the pilots' control strategies, compared and contrasted with both the OCM estimates and the crossover model expectations; 4) interpretations of the results as far as their implications for the moving-base simulation itself.

The display used for the fixed-base simulation was a simple error bar on an oscilloscope. The transfer function models of Table 2, plus other variations as needed, were mechanized on an analog computer to avoid undesirable computational time delays. A digital computer handled all protocol and recorded pilot describing function data. For the majority of the simulation, a McFadden control force loader was used for the control stick, with the stick force/deflection characteristics set at a level preferred by the pilots; a few runs were later made with a stick whose feel characteristics were fixed. Three pilots were involved in the evaluations. All evaluations required the pilots to minimize displayed error in the presence of degraded aircraft dynamics. No non-control (managerial) tasks were attempted.

B. REVIEW OF RESULTS

While the five pitch and four roll transfer-function models of Table 2 were of interest in the simulation, many more configurations were included as needed throughout the sessions to elicit specific pilot ratings and to bracket the response characteristics of the primary cases. For example, short-period frequency variations were included (ω_{sp} = 1, 5, and 7 rad/sec), as were more intermediate values of time delay (τ = 0.033, 0.1, and 0.2 sec) and short-period damping ratio (ζ_{sp} = 0.18, 0.2, 0.3, 0.5, and 0.8). Configurations representative of idealized unstable plants were also included ($Y_c = k/s^2$ and $k/(s-2)$). In summary, a total of 20 pitch and 12 roll dynamics models were evaluated by at least one of the three pilots in single-axis tracking. In addition, 12 pitch and 11 roll cases were evaluated at least once in various dual-axis combinations, resulting in HQRs for a total of 41 two-axis configurations.

Handling Quality Rating summaries for all configurations are given in Appendix A; Table 8 lists the HQRs for the primary cases. Included in Table 8 are the single-axis HQRs for the three pilots, all HQRs for two-axis evaluations, and average ratings. Ratings for repeat runs are indicated for each case. As Table 8 reflects, not all combinations of configurations were evaluated in the brief fixed-base program, and of those that were, most were evaluated by only two pilots. Pilots J and M were the primary subjects, while Pilot H ran only a few of the cases.

Any inter-pilot rating variations can be seen by crossplotting all of the HQRs (averaged for each pilot) for those cases that were evaluated by more than one pilot. Figure 19 shows such a crossplot for Pilot H vs. Pilots J and M, and Pilot J vs. Pilot M. Because of the relatively small number points to be plotted from Table 8, the plots in Figure 19 have been augmented by including average ratings for the additional configurations documented in Appendix A; ratings for the primary cases are denoted by solid symbols. Based on Figure 19, it appears that Pilot H tended to rate all configurations about 1/2 to 1 rating point higher (larger in number) than Pilot J (top plot). There is a similar, though weaker, trend for Pilot H compared to Pilot M (middle plot), at least for the primary single-axis (pitch and roll) cases. There is no clear overall difference

TABLE 8. HQRS FOR PRIMARY EVALUATION CONFIGURATIONS FROM STI SIMULATION

HQRs are: Pilot H/Pilot J/Pilot M (Avg. HQR)

			ROLL	$1/T_R$ (rad/sec)	100†	0.5	0.5	4.0
				τ (sec)	0.0	0.067	0.20	0.067
PITCH				STI Case I.D.	J	B	G	D
ζ_{sp} (−)	ω_{sp} (rad/sec)	τ (sec)	STI Case I.D.	Single-Axis HQRs	2/2,1/1, 1.5,2 (1.58)	-/4/- (4.0)	6/6,6, 4,4,5/6 (5.29)	3/3,3, 1,2,2/2, 3(2.38)
4.526*	11.18	0.0	11	2/2,2,2/2,2 (2.0)	3/2,2/2, 2,2(2.1)		-/6,7/- (6.5)	-/-/3 (3.0)
0.80	5.0	0.033	3	3,4/2,2,2/3 (2.67)	3/-/4 (3.5)			4/3,2/5 (3.5)
0.80	5.0	0.20	8	4/4,4,3/4, 4,5,3(3.88)			-/7/- (7.0)	-/3/5 (4.0)
0.18**	5.0	0.033	2	-/4/- (4.0)		-/7/- (7.0)		
0.18	5.0	0.20	5	6/6,5/6,6 (5.8)			-/7.5/8 (7.75)	-/-/7 (7.0)

*For LAMARS simulation, this gives $\theta/\theta_c = 1/[s(s + 100)]$; for STI simulation, a pure $\theta/\theta_c = 1/s$ was used.

**ζ_{sp} = 0.20 for STI simulation case.

† For STI simulation, $1/T_R = \infty$, i.e., $\phi/\phi_c = 1/s$

Transfer Function Forms:

Pitch: $$\frac{\theta}{\theta_c} = \frac{\omega_{sp}^2/1.25\ (s + 1.25)e^{-\tau s}}{s[s^2 + 2\zeta_{sp}\ \omega_{sp}s + \omega_{sp}^2]}$$

Roll: $$\frac{\phi}{\phi_c} = \frac{1/T_R\ e^{-\tau s}}{s(s + 1/T_R)}$$

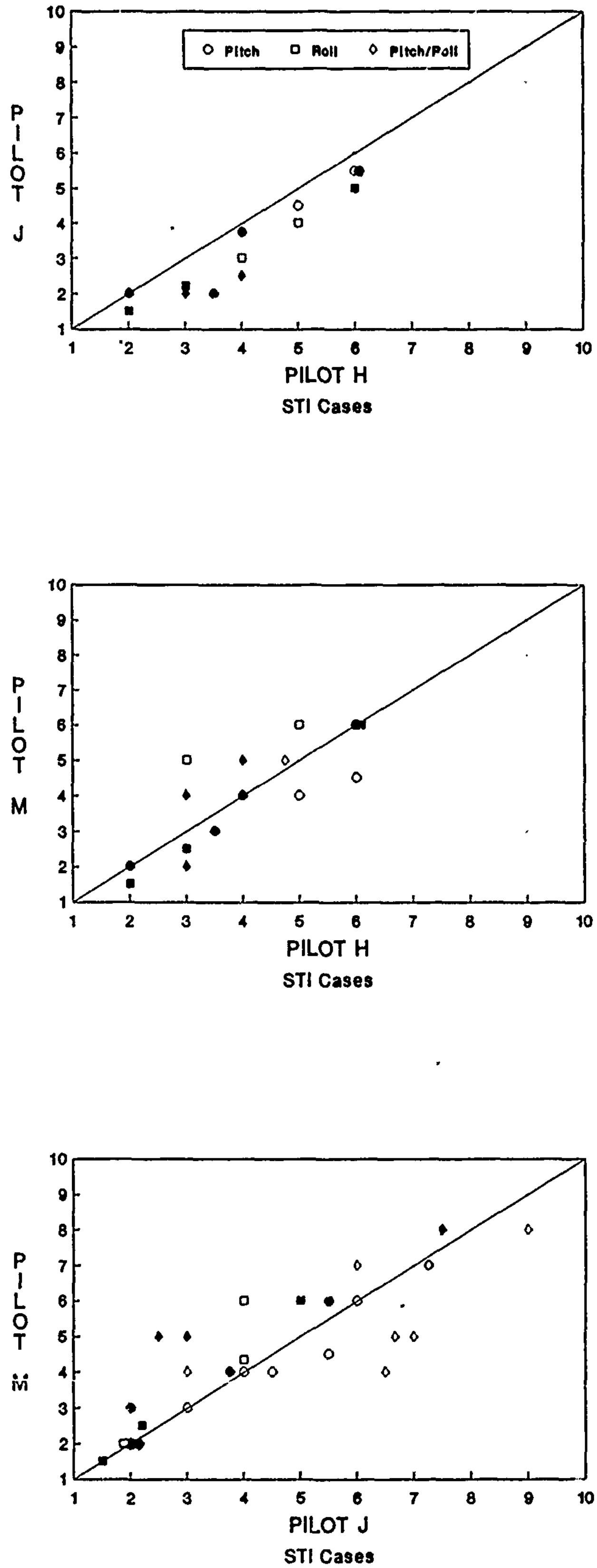


Figure 19. Inter-Pilot Rating Variations (Average HQRs; All Cases; Solid Symbols Denote Primary Cases from Table 8)

in the ratings between Pilots J and M (bottom plot), although Pilot M rated all of the primary cases the same as, or higher than, Pilot J. Variation between Pilots J and M also appears larger, and there are three factors to explain this scatter: 1) since Pilots J and M flew more configurations, there are simply more HQRs to plot, and more scatter may be expected; 2) the greatest HQR differences (2 to 2-1/2 rating points) are all for the two-axis cases, where all pilots expressed some difficulty in judging overall task performance since the error bar translated vertically (in response to pitch errors) and rotated (in response to roll errors) simultaneously; and 3) Pilot M was the least experienced of the three, with the least exposure to the task and simulation setup. In any event, the difference in HQRs between Pilots J and M is still not considered to be significant.

Intra-pilot rating variations for the primary cases can be seen by reviewing the HQR summary in Table 8: the largest difference in HQRs for any one pilot and one configuration is 2 rating points (two cases), and in only one case (Pilot M, pitch Case 8, HQRs 4, 4, 5, and 3) is this spread across Level boundaries. Similar trends are found for all of the additional configurations evaluated (Appendix A), indicating strong intra-pilot consistency run-to-run.

The HQRs in Table 8 indicate that several of the goals of the configuration matrix were achieved: 1) there is a range of HQRs from solid Level 1 to solid Level 3; 2) the single-axis cases cover the range from high Level 1 to Level 2 (although the expected Level 3 ratings for the more degraded single-axis cases were not attained; this is discussed more in the next subsection); and 3) multi-axis ratings from Level 1 through Level 3 were achieved by combining the single-axis cases.

Measures of pilot-vehicle performance (describing functions) were recorded throughout the fixed-base simulation. These measures provide a means of quantifying pilot behavior and verifying that the desired closed-loop operations were achieved. For the latter, since the intent in the simulation was to produce continuous compensatory tracking by the pilots, the primary measure is the describing function for the pilot-plus-vehicle, Y_pY_c; if compensatory tracking has taken place, the frequency-response

plot of the effective transfer function of Y_pY_c will exhibit the characteristics of the crossover model (Reference 16), i.e., the amplitude ratio of Y_pY_c will be essentially k/s-like (slope of -20 dB/decade on a log scale) around the crossover frequency.

Figures 20 and 21 show example pilot-vehicle describing functions of Y_pY_c for the ideal plant, $Y_c = k/s$. If any non-compensatory operations (e.g., pursuit of certain dominant frequencies of the forcing function) occurred, they would most clearly show up with this controlled element. Symbols in Figures 20 and 21 are plotted at the frequencies of the sum-of-sines forcing function input (see Appendix A), and exhibit pure compensatory behavior: the amplitude ratios are k/s-like around crossover (i.e., the pilots did not have to alter the characteristics of the open-loop transfer function to perform the tracking task); crossover frequencies range from 2.6 to 3.5 rad/sec, as expected from theory, Reference 16; the roll-off in phase due to the pilots' effective time delay shows no higher-order behavior.

Based on the describing function plots of Figures 20 and 21, and others shown later in this section, it is clear that compensatory tracking occurred as desired, and that the experimental design was appropriate for obtaining valid performance and handling qualities information. Figure 22 summarizes the more important performance measures from all three pilots for all of the primary pitch and roll (single-axis) cases. The plot shows normalized performance, $\bar{e}/\sigma_c$; crossover frequency, ω_c; phase margin, Φ_M; and HQR. Normalized performance is an indication of how well the pilot was able to reduce the forcing function error ($\bar{e}/\sigma_c = 1.0$ indicates no error reduction). All values are averages for all evaluations (last run only; Pilots J and M flew two runs for each case before assigning an HQR and the first run was considered a training run for this analysis), with spreads in the values indicated where appropriate.

Figure 22 shows a definite relationship between HQR and performance, as expected since closed-loop performance is a major factor in the assignment of pilot ratings. There is a trend toward lower crossover frequencies as the handling qualities degrade as well. Phase margin variations are consistent between pilots, but show different trends for

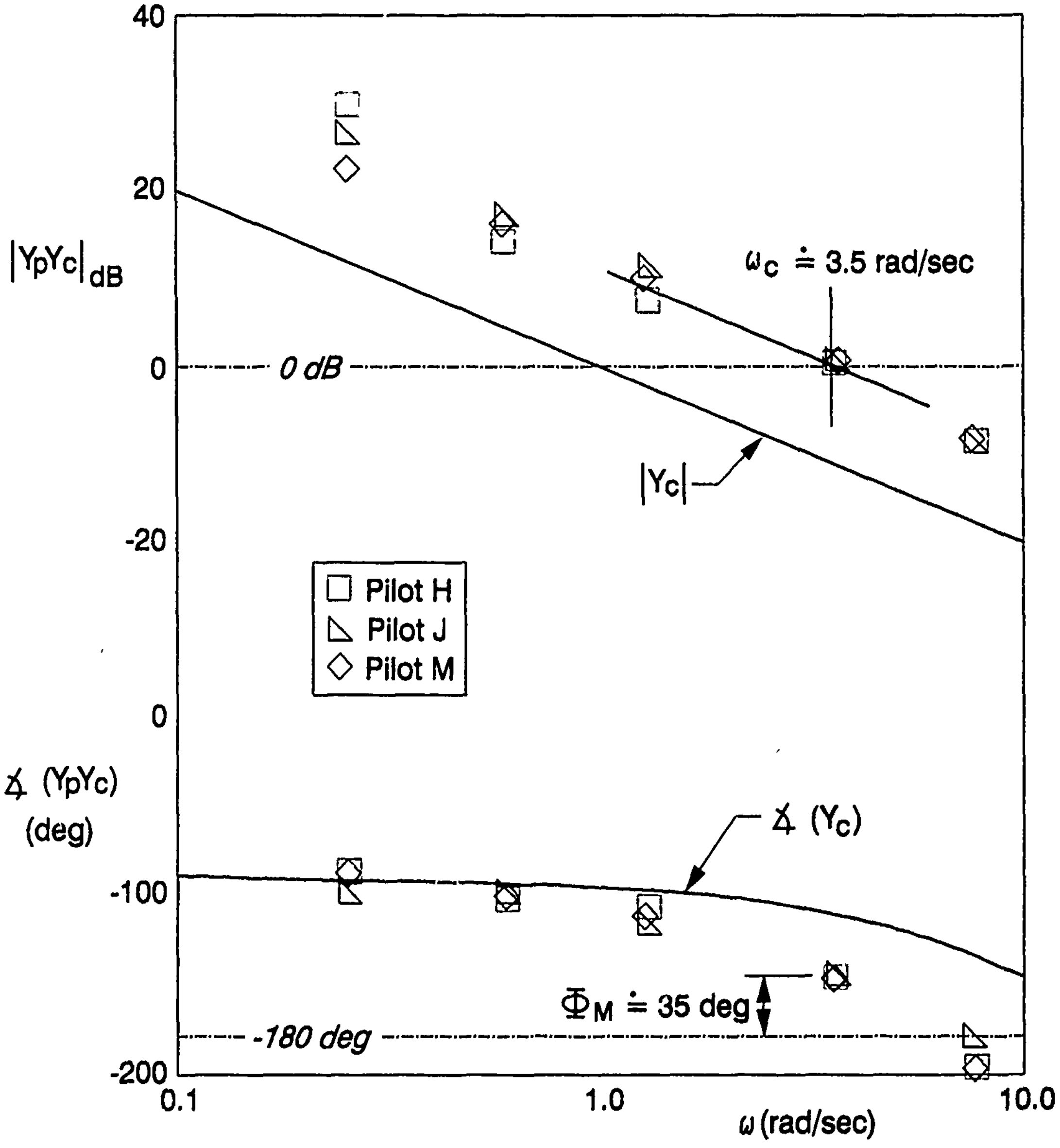


Figure 20. Frequency Responses of Y_pY_c for Y_c = k/s from Fixed-Base Simulation (Roll Case 11; Feel System Included in Y_c)

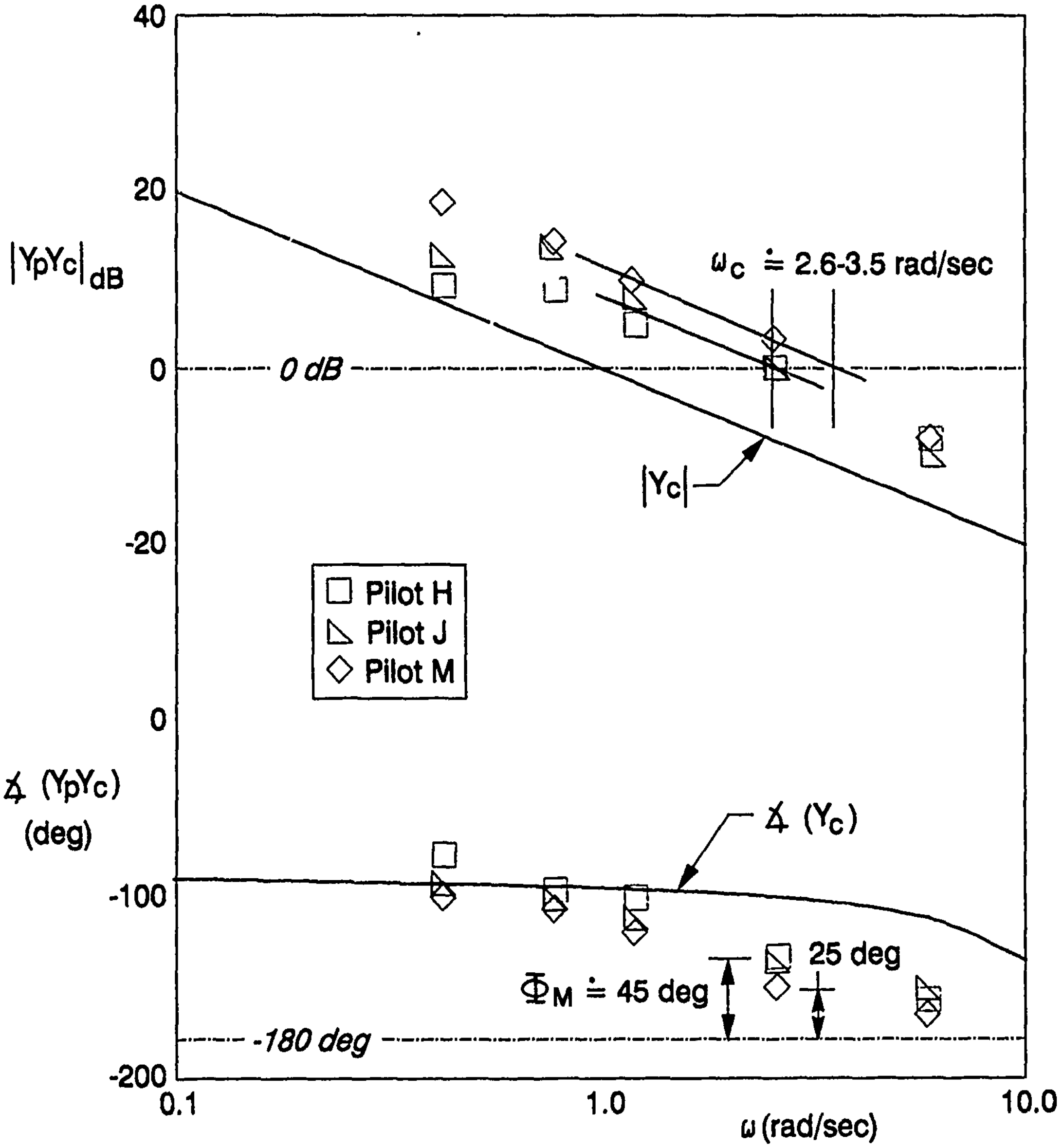


Figure 21. Frequency Responses of Y_pY_c for Y_c = k/s from Fixed-Base Simulation (Roll Case J; Feel System Included in Y_c)

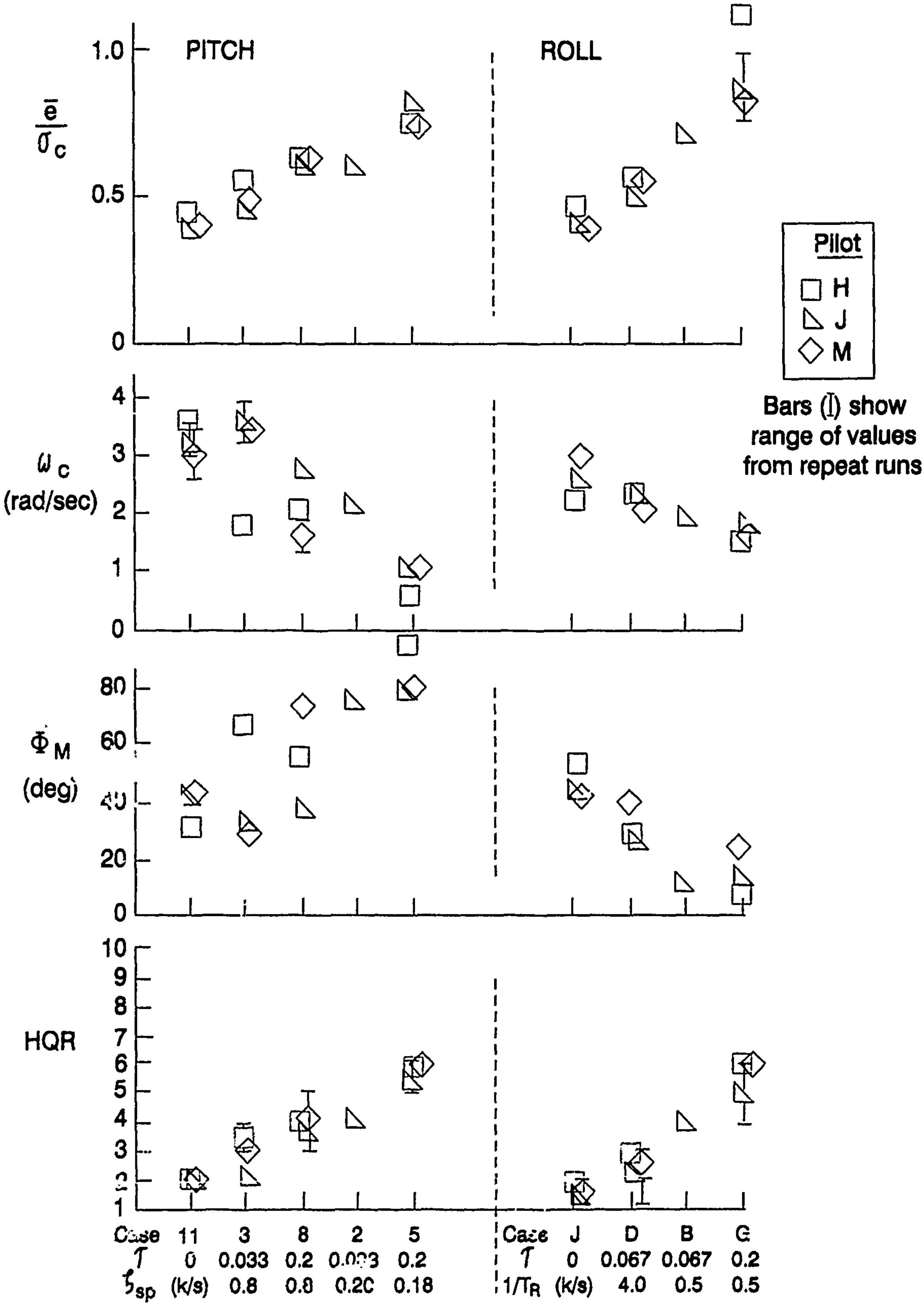


Figure 22. Summary of Pilot Performance for Primary Cases from Fixed-Base Simulation (Averages for Last-Run Data)

the pitch and roll configurations overall. For the pitch cases, the high short-period frequency produces a large airplane-alone phase margin (90 – 130 deg at frequencies near crossover), requiring the pilots to generate an effective lag. The dynamics of the roll cause are fundamentally different in form, with increasing phase lag as the dynamics degrade (90 deg for Case J, 0 deg for Case G), requiring a net lead to improve the closed-loop dynamics. This, as the aircraft dynamics degrade, phase margin increases for the pitch cases and decreases for roll – both reflecting the vehicle-alone phase characteristic. There are no significant, consistent differences between pilots for any of the performance measures of Figure 22.

C. COMPARISON WITH HANDLING QUALITIES CRITERIA

This subsection compares che results of the fixed-base simulation with the flying qualities Level estimates from Section III. Additional analyses are applied to those criteria that allowed estimates of expected HQRs, and to the results of the OCM, where pilot behavior can be compared.

1. Flying Quality Level Estimates from Single-Axis Criteria

The single-axis flying quality Level estimates of Table 6 are compared with the actual Levels from the fixed-base simulation in Table 9. For this comparison, predicted flying quality Levels of ">3" (Table 6) were considered to be a fictitious "Level 4". Based on Table 9, the following observations can be made.

The flying quality Levels for all cases are, in general, better than estimated (the exceptions, OCM and descriptors, are discussed below). Several factors may have contributed to the better HQRs: 1) in pitch, the effects of low short-period damping on handling qualities may have been lessened by using a fixed-base facility. 2) The requirements on short-period damping in the military standard are known to be conservative (e.g., Reference 2) as a protection against gust sensitivity. Most flight test programs that were conducted to gather information on short-period damping (Reference 2) were flown only in calm conditions, and the majority of the supporting data for short-period damping requirements suggest that

TABLE 9. COMPARISON OF FLYING QUALITIES LEVEL ESTIMATES WITH RESULTS OF FIXED-BASE SIMULATION

EXPERIMENT			ΔLEVEL (EST.–EXPER.)*							
CASE	AVG. HQR	LEVEL	CAP	$\omega_{sp}T_{\theta 2}$	TPR	PILOT-IN THE-LOOP	BANDWIDTH	NEAL-SMITH	OCM	DESCRIPTORS
11	2.0	1	–	–	0	0	0	0	0	0
3	2.7	1	+1	+1	0	+1	+1	0	0	0
8	3.88	2	+2	+2	+2	+1	+1	0	-1	0
2	4.0	2	0	0	0	+1	+1	+1	-1	0
5	5.3	2	+2	+2	+2	+1	+2	+1	-1	+1

	EXPERIMENT		ΔLEVEL (EST.–EXPER.)*			
CASE	AVG. HQR	LEVEL	MIL-STD-1797 (T_R, τ_{ep})	LATHOS	OCM	DESCRIPTORS
J	1.6	1	0	+2	0	0
B	4.0	2	+1	+2	0	0
G	5.3	2	+2	+2	0	0
D	2.4	1	+1	+2	0	0

*ΔLEVEL > 0 Indicates Criteria Predicted Worse Flying Qualities Level

the lower limits could be relaxed. Since the tracking tasks performed here were conducted in the absence of any external turbulence, the more lenient limits on short-period might be appropriate, and a damping ratio of 0.18 - 0.2 would be Level 2, rather than Level 3 as specified in MIL-STD-1797. 3) The ratings for the roll configurations are likewise better than estimated, due to a combination of a lack of motion cues and the use of "ideal" airplanes: no Dutch roll contamination, sides, , Review of the supporting data in Appendix A of MIL-STD-1797 (Reference 2) indicates that similar fixed-base data have suggested a lower Level 1 limit on T_R of 2.0 sec, rather than 1.0 sec as specified in MIL-STD-1797. Thus, the better ratings for the roll configurations are not entirely surprising.

The CAP and $\omega_{sp}T_{\theta_2}$ requirements (including τ_θ limits) predicted worse flying qualities in general because of equivalent time delay. Flight tests by NASA with a fly-by-wire F-8 (Reference 18) show Level 1 HQRs for total time delays as great as 130-150 msec, so the MIL-STD-1797 limits may be somewhat conservative. The transient peak ratio (TPR) requirements of MIL-STD-1797 also reflect conservative time delay limits, resulting in predictions of worse flying qualities for pitch Cases 5 and 8.

The pilot-in-the-loop (modified Neal-Smith) and bandwidth criteria from MIL-STD-1797, as well as the original Neal-Smith criteria of Reference 8, all reflect very conservative limits as a result of the primary data base used for their development: the flight tests of Reference 8. Analyses of these flight test data have shown several unconventional characteristics that result in extremely conservative flying qualities requirements (Reference 19).

The OCM estimates for pitch flying qualities do not recognize the high time delays and low damping ratios of the degraded configurations, and hence are the only estimates for better handling qualities. More analysis of the OCM is given later in this section. The estimated Levels based on descriptions of the configurations actually come closest to correctly predicting the pitch flying qualities.

In roll, the MIL-STD-1797 requirements on both T_R and τ_e appear too stringent, though the near-ideal conditions for the simulation may have

resulted in better HQRs than expected. All of the LATHOS estimates are much too conservative, since the LATHOS time domain requirements place stringent limits on both lower and upper values of roll damping. The OCM estimates and the estimates based on adjectival descriptions correctly estimated the flying qualities Levels for all four of the roll cases.

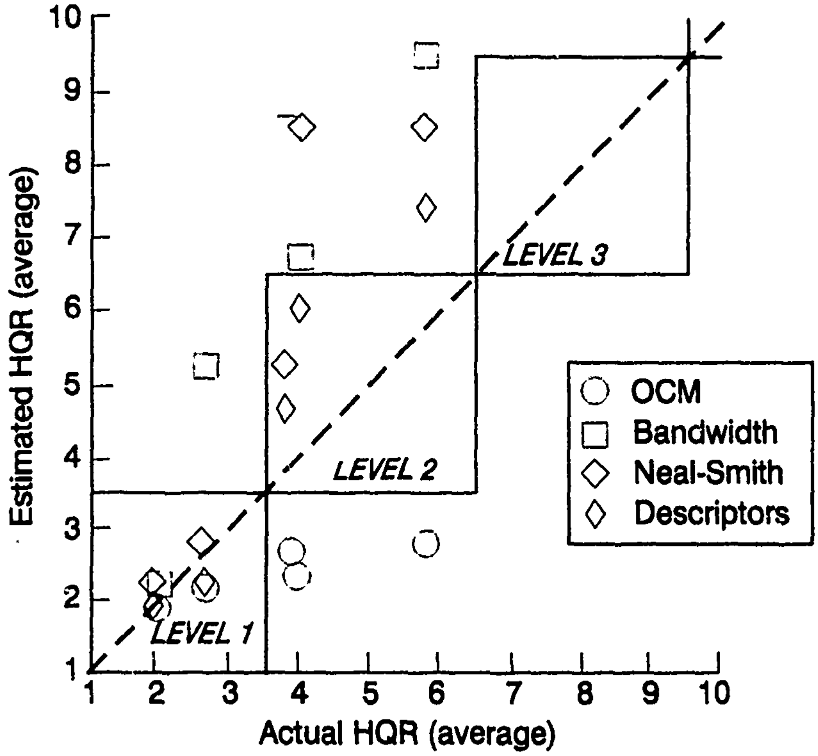
2. Handling Quality Rating Estimates from Single-Axis Criteria

Rough estimates of expected HQR were made based on the bandwidth and Neal-Smith criteria, and were generated directly from the OCM applications and the descriptions (Table 6) for the five pitch cases. These estimates are crossplotted with the actual average ratings for the pitch cases in Figure 23a. The OCM (circle symbols) shows a lack of sensitivity to the degraded flying qualities, while all other criteria (including, to a small degree, the adjectival descriptions) are overly sensitive. Similar HQR estimates from the LATHOS criteria and the OCM and description applications were made for the four roll cases, and these comparisons are shown in Figure 23b. This figure reflects the extremely conservative nature of the LATHOS limits, as well as the success of the OCM for estimating roll flying qualities.

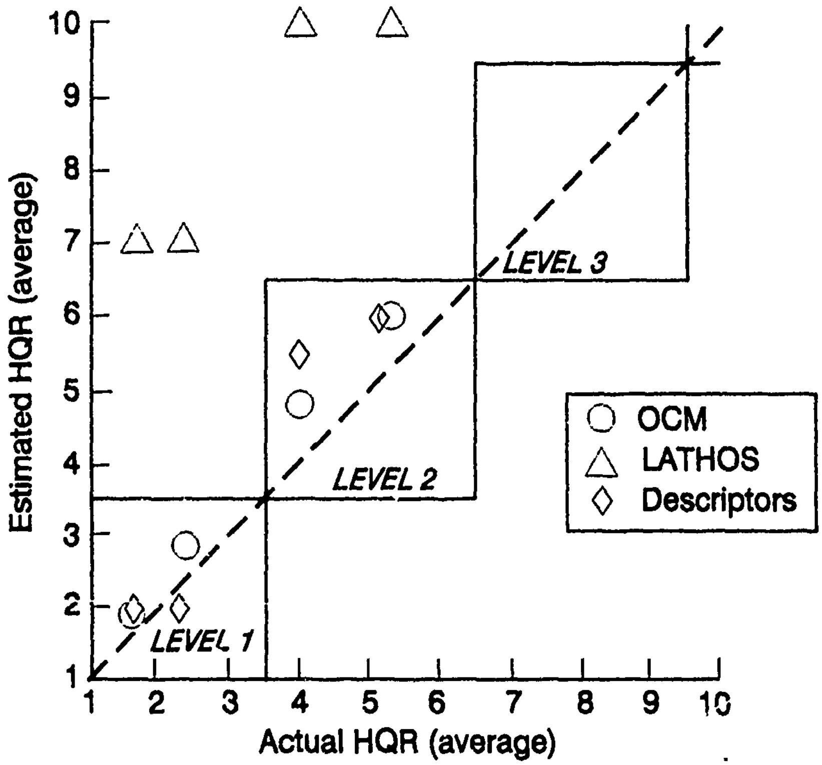
3. Application of Multi-Axis Criteria

Estimates of HQRs for the two-axis (pitch and roll) situation were made by combining the bandwidth and LATHOS, Neal-Smith and LATHOS, and single-axis description estimates through the Product Rule (Table 7). Additional two-axis HQRs were generated by the OCM, but only for three of the five pitch cases (Table 5; it was recognized that the single-axis estimates from the OCM for pitch Cases 2 and 5 were bad, so these cases were dropped from the multi-axis work).

Figure 24 shows a summary crossplot of all multi-axis rating estimates with the actual average ratings from the fixed-base simulation. The conservative single-axis estimates for the bandwidth, Neal-Smith, and LATHOS criteria result in expected dual-axis HQRs of 7 to 10. Only the OCM and description estimates appear to work well -- but one must bear in mind that the OCM estimates for three dual-axis cases (2B, 5G, and 5D)



a) Pitch Tracking Task



b) Roll Tracking Task

Figure 23. Crossplot of Average Pilot Ratings from the Fixed-Base Simulation with Estimated Single-Axis Ratings

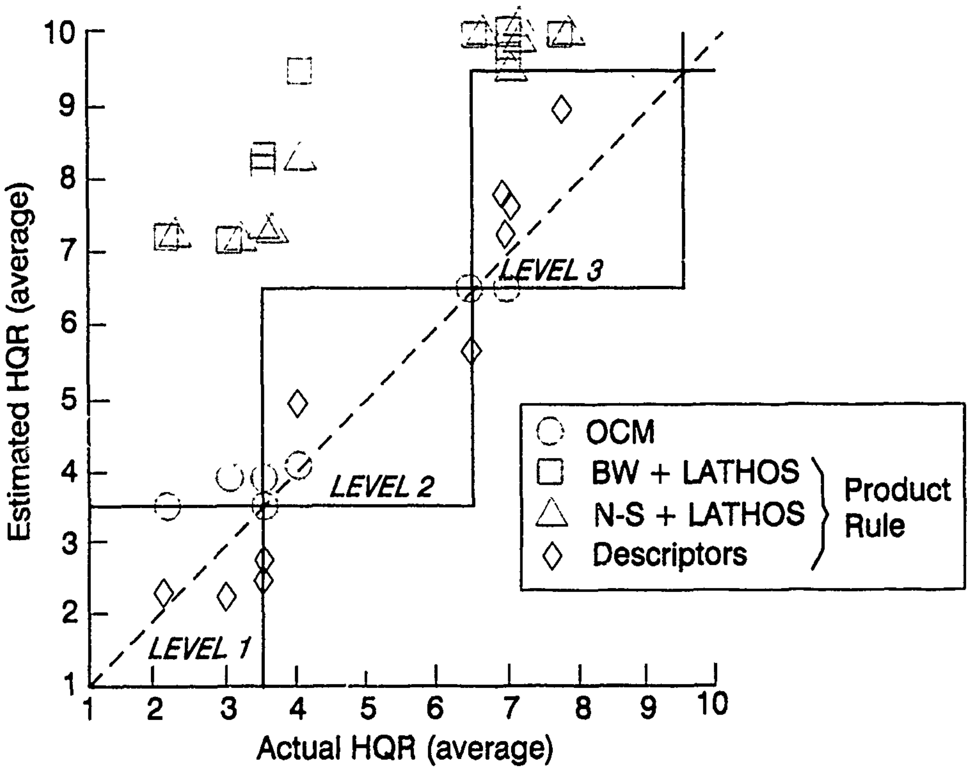


Figure 24. Crossplot of Average Pilot Ratings from the Fixed-Base Simulation with Estimated Ratings (Dual-Axis Task; Cases 2B, 5G, and 5D not Computed for OCM -- see Text)

were not made, as mentioned above, and that the estimated HQRs for these cases would reduce the success rate of the OCM.

D. MEASURES OF DIVIDED-ATTENTION OPERATION

The theory of divided attention (described in detail in Volume II of this report) states that pilot behavior will change in conditions of divided operator attention, whether the source is a non-control task, or simply addition of axes to control. In this simulation, the extension from single-axis tracking in either pitch or roll to simultaneous tracking of both axes was used to investigate divided-attention operations. Several measures of divided attention can be applied (see Volume II); for this analysis, the most straightforward measure is crossover frequency.

The pilots were instructed in all cases to attempt to null displayed errors to the extent possible, given degraded aircraft dynamics. Based on the divided-attention theory, therefore, a pilot should not be able to control two axes simultaneously as well as he might control either axis alone, and further, there should be a shifting of priorities if one axis is significantly more degraded than the other. In terms of crossover frequencies, this corresponds to a change in the crossover frequency in each axis for the dual-axis case, compared to the respective single-axis cases. As a simple example, we might expect that if a pilot were able to achieve a crossover frequency of 3.5 rad/sec for the k/s model in pitch (Case 11) when tracking pitch alone, and likewise in roll (Case J) when tracking roll alone, the combination (Case 11J) should result in crossover frequencies in both axes somewhat less than 3.5 rad/sec.

A simple metric for verifying the theory of divided attention is a crossplot of crossover frequency ratios, i.e., the ratio of ω_c(dual-axis)/ω_c(single-axis) for pitch vs. ω_c(dual-axis)/ω_c(single-axis) for roll. Such a crossplot is given in Figure 25 for each pilot from fixed-base simulation. Figure 25a gives guidance on interpretation the crossplots. Figures 25b, c, and d show the results for Pilots H, J, and M, respectively, with all data from Appendix A included. Pilot H, who had the fewest hours in the simulator, has the least amount of data. The crossover frequency ratios for his data show no consistent trends, though most of the points have ratios less than one, suggesting a more or less equal reduction in ω_c in both axes going from single-axis to dual-axis tracking. The greatest exception is a case for which the pitch crossover frequency was twice as high, and roll almost 1.5 times higher. Trends for Pilot J are somewhat stronger (Figure 25c): the vast majority of his data indicate a reduction in crossover frequencies in both pitch and roll when compared to the single-axis cases, suggesting that Pilot J divided his attention essentially evenly between axes in the dual-axis tracking runs. For Pilot M (Figure 25d), there is an indication attempts to maintain constant performance in roll no matter what was required in pitch, i.e., the data are clustered along the line for $\omega_{c_2}/\omega_{c_1}$(roll) = 1.0. Both Pilots J and M occasionally improved performance in one axis in the dual-axis situation.

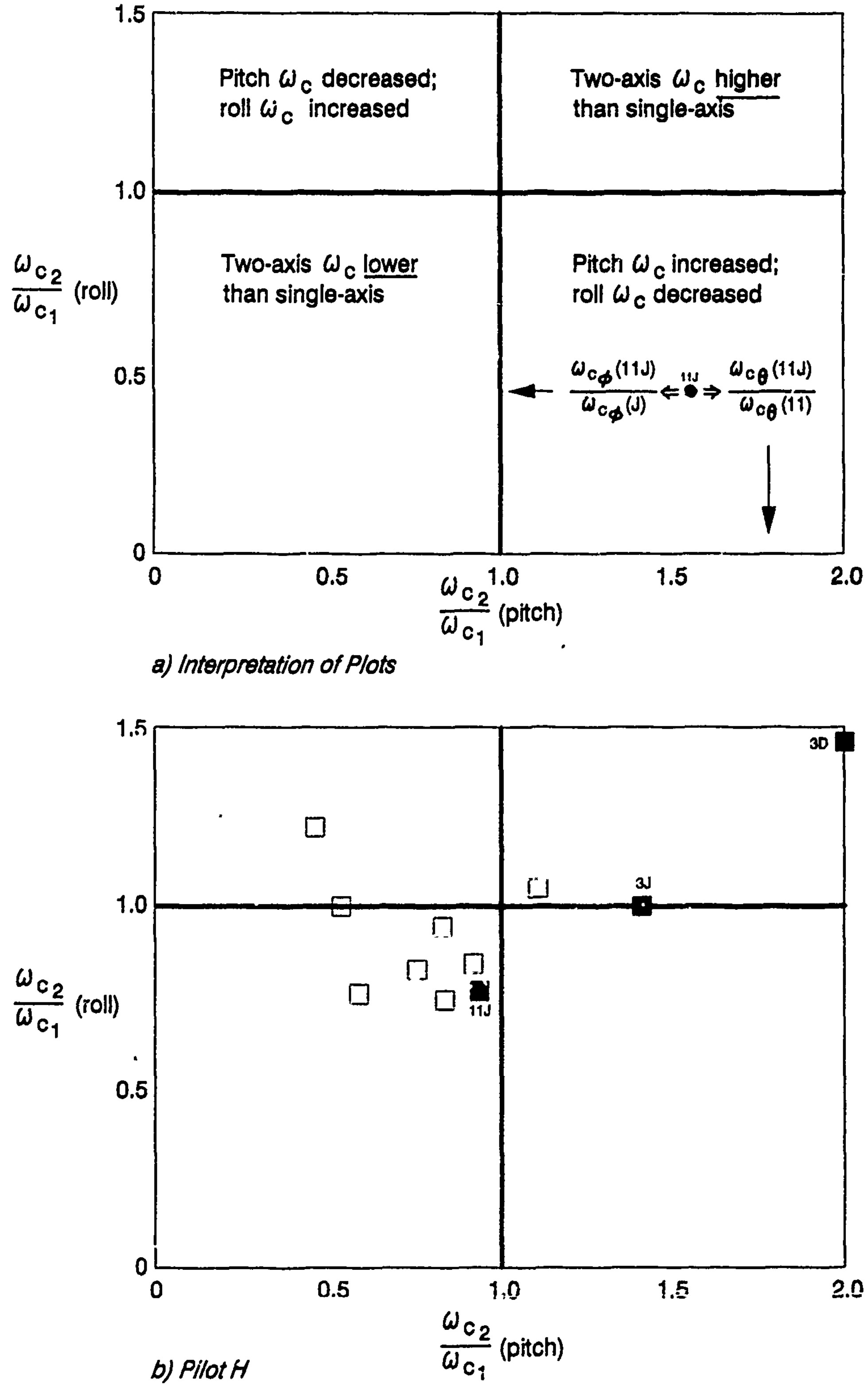
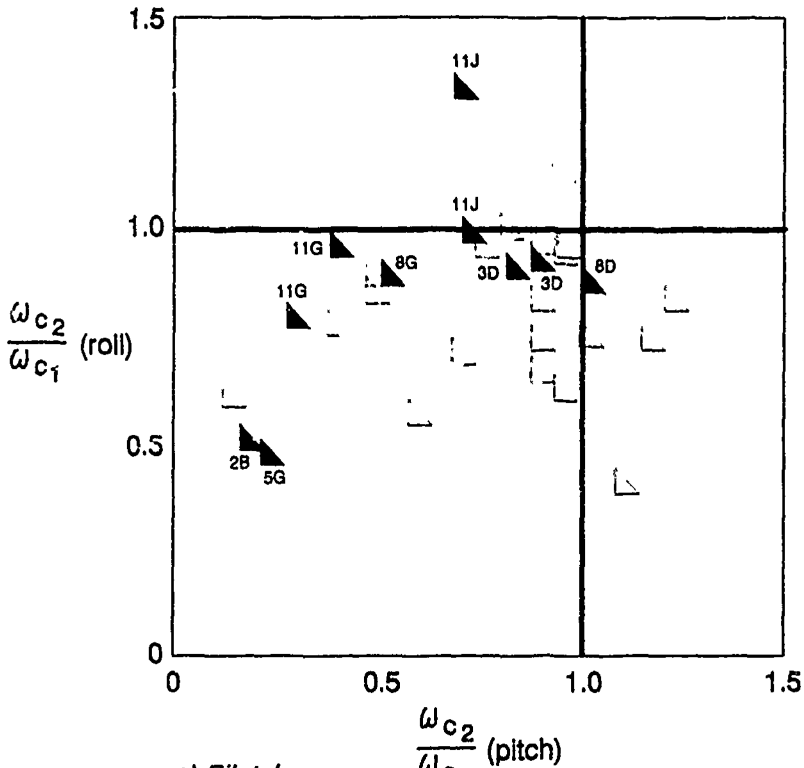
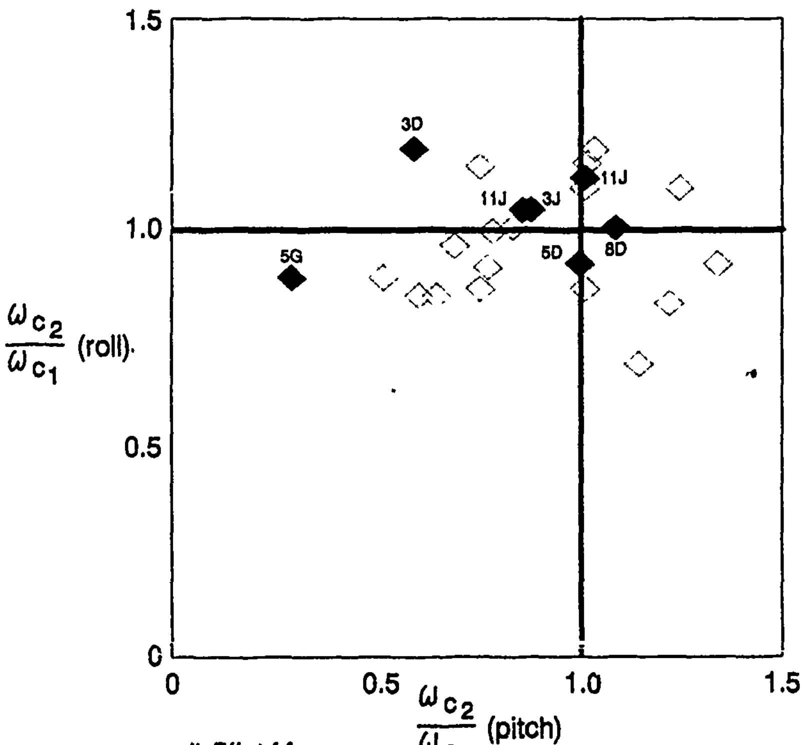


Figure 25. Crossover Frequency Ratios for Pilots from Fixed-Base Simulation (Two-Axis/Single-Axis; Primary Cases are Labeled)



c) Pilot J



d) Pilot M

Figure 25. (Concluded)

E. PILOT MODEL ESTIMATES FROM THE OPTIMAL CONTROL MODEL

The most promising overall criteria reviewed above are those based on the Optimal Control Model (OCM) of Volume I. It was shown that the OCM accurately estimated the HQRs for the four roll configurations, and for two of the five pitch cases. Since the OCM also generates estimates of pilot behavior, the output from OCM can be compared with describing-function measures of actual pilot behavior to examine its weaknesses.

Figure 26 shows the pilot-vehicle (Y_pY_c) describing function data of Figure 20, for the Y_c = k/s system (pitch Case 11), with the OCM estimates added. The OCM predicts crossover frequency extremely well, and exhibits the proper k/s-like characteristics near crossover. Differences occur at low frequencies, where the OCM adds a lead at 0.54 rad/sec, and at all frequencies in phase angle as a result of this lead. The estimated phase margin of 77 deg is well above the experimental value of approximately 35 deg. The pilots did not seem to require such a low-frequency lead term, and hence the actual describing functions are approximately -20 dB/decade for the entire range, with lower overall phase characteristics.

It was shown in the preceding section that the OCM has its greatest problems with configurations that require lag compensation near crossover; the best example of this is pitch Case 5, where the OCM estimate of HQR is far from the actual experimental average (Table 9). Figure 27 is the frequency response for this case. The pilot-vehicle describing functions from the simulation (symbols) show quite interesting behavior in themselves, as all three of the pilots were able to control this configuration quite well and obtain relatively high crossover frequencies (ranging from 0.6 to 1.3 rad/sec) in light of the extremely lightly damped short-period mode. THe simple crossover model analysis in the previous section showed that with an assumption of pure pilot lag at $1/T_{\theta_2}$ and a requirement to maintain a 3 dB gain margin on the lightly-damped short-period, crossover frequency would probably not exceed 1 rad/sec, and at the expense of very low phase margins. Figure 27 shows that the pilots were able to do even better, possibly improving phase margin with high-frequency lead. The OCM estimate of pilot behavior, however, is very pessimistic: the OCM pilot simply backs off in gain, choosing to live with extremely low crossover

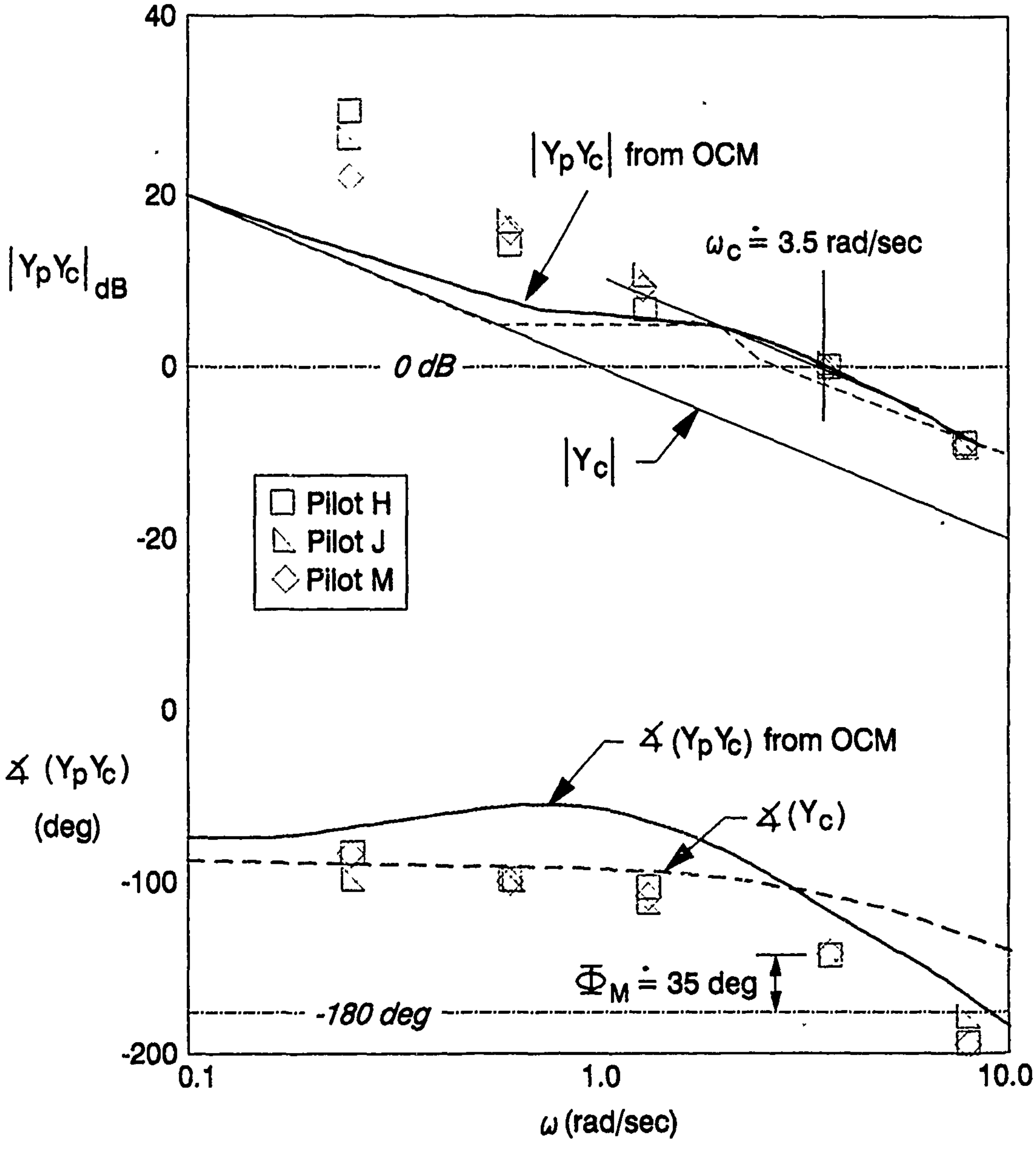


Figure 26. Frequency Responses of Y_pY_c for Pitch Case 11 ($Y_c = k/s$) Compared to OCM Estimates

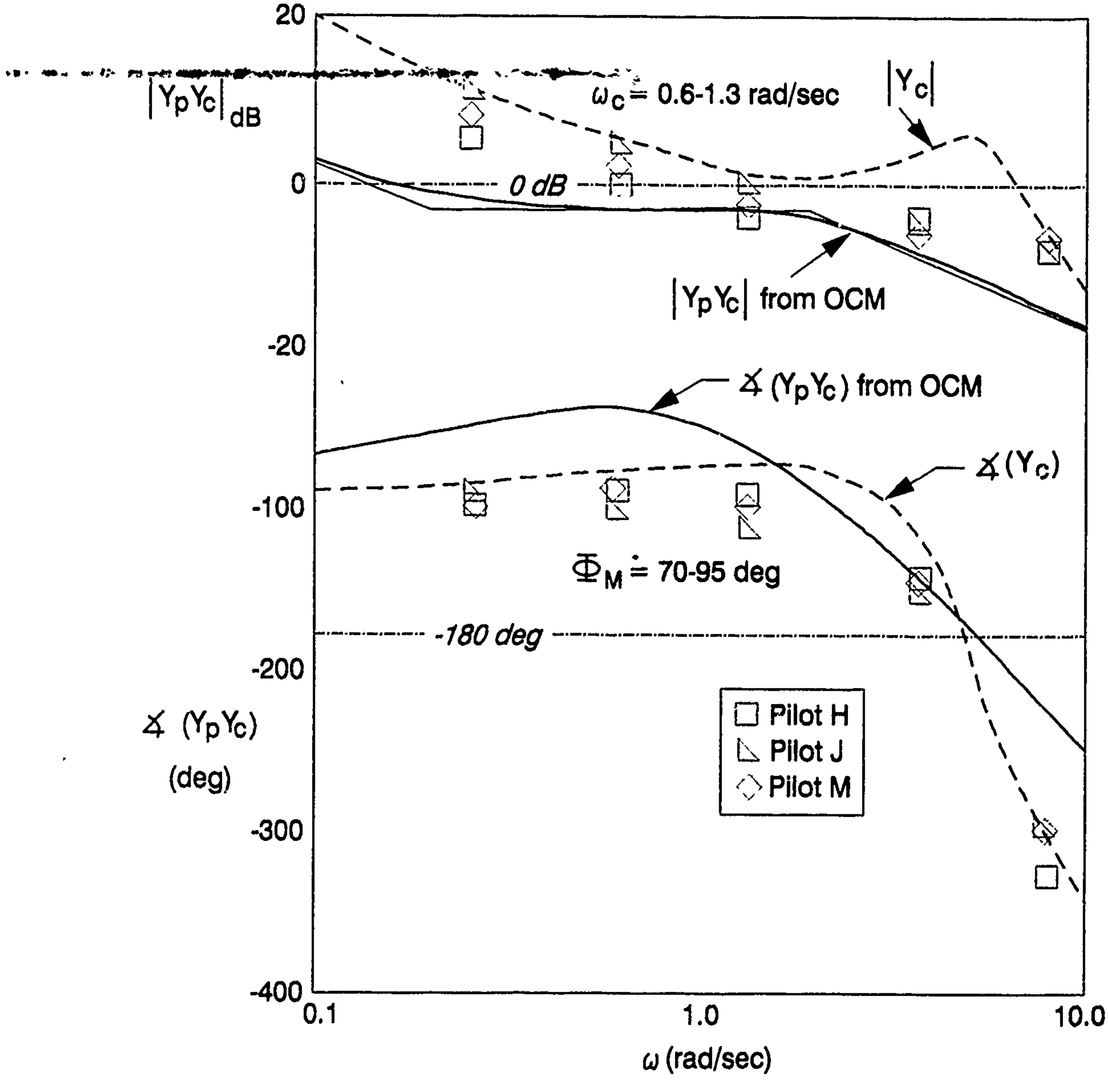


Figure 27. Frequency Responses of Y_pY_c for Pitch Case 5 Compared to OCM Estimates

frequencies and the attendant high displayed errors rather than risk exciting the short-period.

As discussed in the previous section, the overall conclusion about the OCM estimates is that the OCM model will not estimate pilot lag to improve closed-loop performance. This is a shortcoming in the OCM approach that deserves much further study and refinement, especially in view of the OCM's relative success with estimating pilot ratings for cases where lead is required -- i.e., the roll configurations (Figure 23b).

F. CORRELATION OF COST FUNCTIONS WITH PILOT RATING FOR OCM ESTIMATES

In the previous section a correlation of HQR with J (appropriately normalized by forcing function bandwidth and amplitude) was used as the basis for estimating HQRs for the fixed-base simulation. The general equation of HQR as a function of J was:

$$\mathrm{HQR} = 5.5 + 3.7 \log_{10} (J/\sigma_c^2 \, \omega_W^2)$$

This equation was derived from optimal-control analysis of the Dander (Reference 3) data, shown in Figure 9. A similar plot for the fixed-base simulation results reported here is given in Figure 28. All of the configurations, with the exception of the lightly-damped cases, fit this correlation line extremely well. Pitch Cases 2 and 5, with low short-period damping, are the exceptions. As with prior plots, the pitch/roll cases 2B, 5D, and 5G will also fail to fit this line and are not shown.

With the appropriate caveats about aircraft that require lag compensation, the general equation for HQR given above works well to estimate handling qualities in pitch, roll, and -- most importantly -- in dual-axis pitch/roll tracking situations.

G. PRODUCT RULE APPLICATION

The Product Rule (Reference 7) states that the HQR for a two-axis tracking task will be worse than the individual HQR for either task single-axis. The Product Rule formula was applied in Section III to

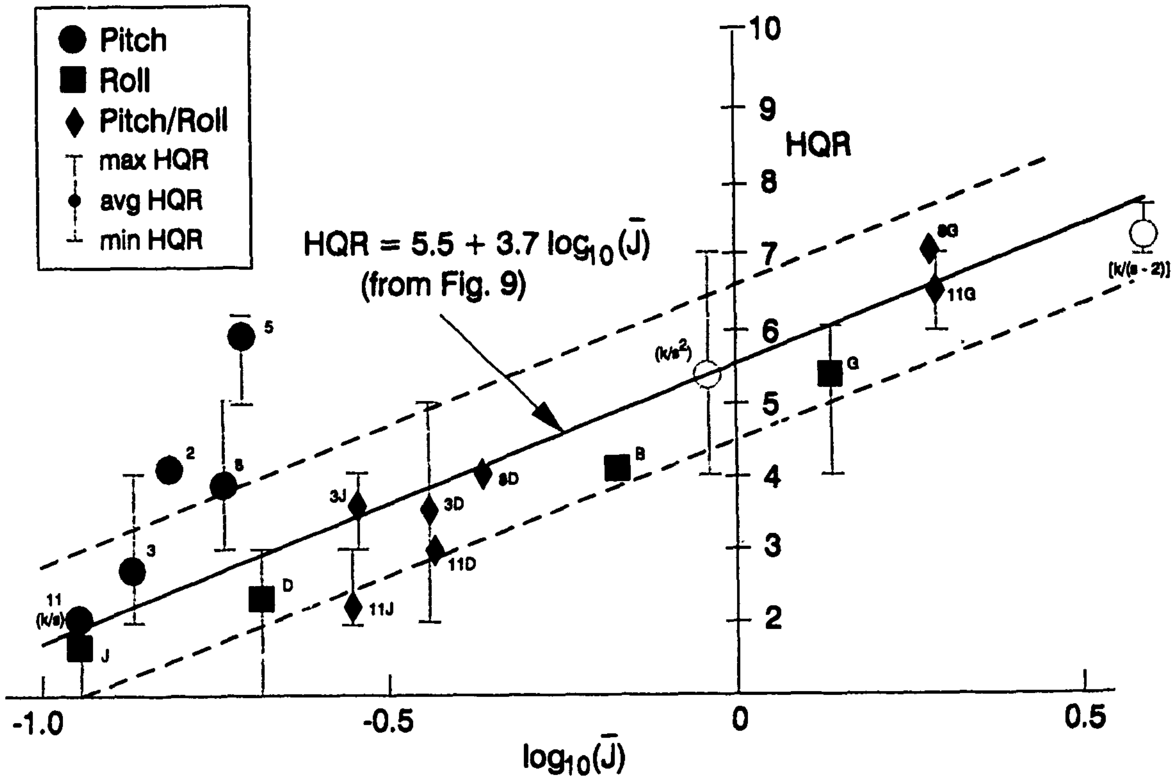


Figure 28. Cost Function/Rating Correlation for Fixed-Base Simulation Data (Cases 2B, 5D, 5G not shown)

$$(\bar{J} = J/(\sigma_c^2\omega_w^2))$$

develop estimates of the dual-axis HQRs, starting from estimates of the single-axis HQRs.

Verification of the Product Rule can be performed by using the actual results from the STI fixed-base simulation. A first check is simply to crossplot the single-axis ratings (pitch vs. roll) from each pilot for each combination that was evaluated in the two-axis task, and note the corresponding multi-axis rating, as is done in Figure 29. (The data of Table 9 have been augmented in Figure 29 by adding the ratings for all multi-axis runs from Appendix A.) Figure 29 confirms the general structure of the Product Rule, i.e., the HQR for any two-axis task is higher than for the corresponding single-axis tasks. Rough boundaries between Levels have been sketched on this figure to emphasize this.

Figure 30 shows the comparisons resulting from applying the Product Rule on the STI data: the multi-axis ratings predicted by applying the Product Rule to the corresponding single-axis ratings are plotted against actual HQRs from the simulation. Correlation is seen to be excellent.

H. IMPLICATIONS OF THE FIXED-BASE SIMULATION RESULTS ON THE MOVING-BASE SIMULATION

The fixed-base simulation conducted at STI provided considerable insight into the applicability of both single-axis and multiple-axis handling qualities criteria for the limited aircraft dynamics matrix selected. Several key observations can be made based on this section, most of which will be addressed in detail in the next section, where revised estimates are made for the moving-base simulation study.

The simulation setup and protocol were valid for eliciting pilot behavior consistent with compensatory tracking. This was essential for extracting pilot-vehicle dynamic information.

Pilot opinion ratings were found to be consistent and repeatable. The tasks and aircraft transfer-function models specified provided the desired range of HQRs.

Most classical flying qualities criteria predicted much worse handling qualities than were found in the simulation. Several effects, including lack of motion cues, ideal aircraft responses, and perhaps overly conservative criteria, contributed to this result. For the moving-base simulation, any attempts to simply re-apply the same criteria would be fruitless, since there is no evidence to suspect any significant change in the HQRs for the same compensatory tracking tasks. Instead, alternative approaches to specifying handling qualities are applied in the next section of this report.

Finally, it will be critical to further validate the simulation tasks by expanding the moving-base simulation to include tasks that are distinctly different in form, but that will perform similar purposes in emphasizing both single- and combined-axis maneuvering.

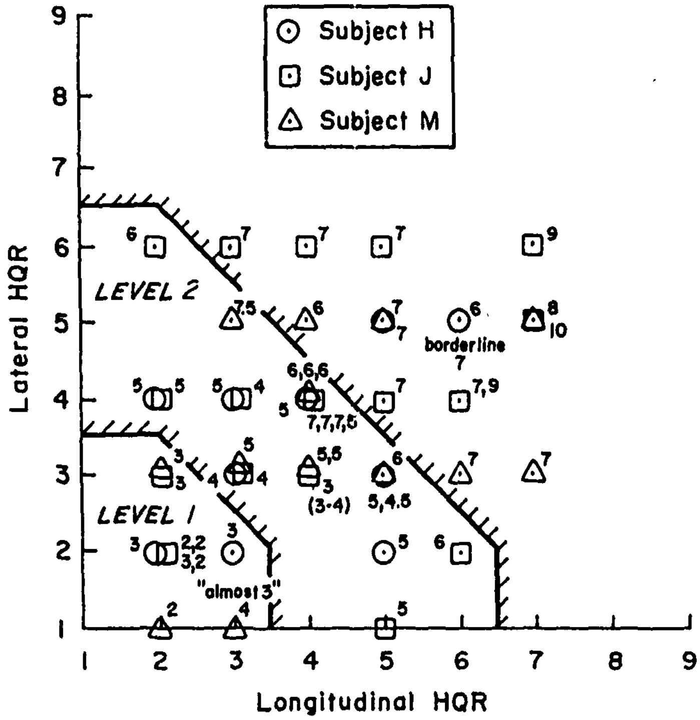


Figure 29. Comparison of Single-Axis (Pitch and Roll) HQRs with Multi-Axis HQRs from STI Simulation

$$R_m = 10 + \frac{1}{(-8.3)^{(m-1)}} \prod^{m} (R_i - 10)$$

$$m = 2$$

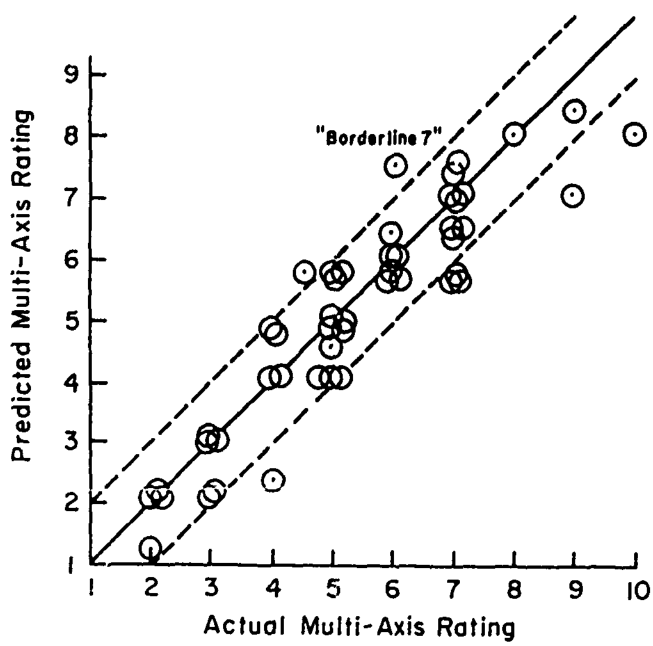


Figure 30. Comparison of Product Rule with Single- and Multi-Axis Pilot Ratings from STI Simulation

SECTION V

REVISED FLYING QUALITIES ESTIMATES FOR MOVING-BASE SIMULATION

A. BACKGROUND

Results of the brief fixed-base simulation reported in the previous section indicated a number of areas where refinement of flying qualities estimates were required. No single criterion discussed in Section III was completely successful at estimating the flying qualities Levels for the primary pitch and roll configurations of Section II. The Optimal Control Model (OCM) came the closest, but it was shown to have difficulties with configurations that required generation of pilot lag near crossover frequency. (The HQR estimates based on adjectival descriptions for the aircraft transfer-function models were actually more successful, but such an approach is considered too highly subjective and too dependent on the expertise of the flying qualities expert to be a repeatable, generally applicable "criterion" for minimum flying qualities.) The combination of HQRs for single-axis tracking into multiple-axis ratings via the Product Rule was shown to be valid -- as long as valid single-axis HQRs are available to begin with.

This section will re-examine the fixed-base simulation results in an effort to develop several revised flying qualities criteria for single-axis tracking, and an overall two-axis criterion that allow estimates of HQRs using purely mathematical expressions in terms of aircraft bandwidth frequency and phase delay. Revised estimates of the expected HQRs for the moving-base simulation will then be made.

B. DEVELOPMENT OF REVISED BANDWIDTH LIMITS

Most of the flying qualities criteria discussed in Section III of this report are intended only to determine the flying qualities Level of a particular aircraft, rather than the estimated pilot rating. This is a reflection of the structure of the military specifications (References 1 and 2), where all requirements are in terms of Levels. The authors of the proposed MIL Standard and Handbook (Reference 20) recommended the use

of HQRs in the structure of the MIL Standard itself, but this recommendation was considered too risky to adopt in the actual MIL Standard.

For the development of minimum flying qualities criteria, however, the focus has been on estimating specific ratings rather than Levels, since the Level structure does not provide sufficient discrimination (i.e., there are three Levels but ten points on the HQR scale). The final check of any criteria is still its effectiveness at correctly estimating Levels.

The only single-axis flying qualities criteria applied in Section II that allow pilot rating estimates are bandwidth, Neal-Smith, and OCM in pitch, and the LATHOS boundaries and OCM in roll. The OCM was shown to work well when applied to certain dynamics, and no further refinement of this approach is possible without considerable additional effort. Of the other criteria, all three (bandwidth, Neal-Smith, LATHOS) predicted much worse flying qualities than the HQRs indicated, suggesting a redefinition of boundaries is justified for all three.

The approach taken here has been to refine the bandwidth criteria boundaries, including definition of roll bandwidth limits. The Neal-Smith criteria were considered too complex for a detailed re-evaluation, and time-domain requirements such as the LATHOS criteria are not as robust as frequency-domain criteria such as bandwidth.

The bandwidth parameters for all of the single-axis HQR data from the STI fixed-base simulation (Appendix A) are plotted in Figure 31. Pilot ratings for the three pilots are noted next to each point; actual ratings, rather than averages, were used to redefine the boundaries. Possible Level 1 limits have been sketched in (solid lines) by inspection of the data. Several important observations can be made from Figure 31:

- The Level 1 limits on pitch bandwidth are significantly lower than those specified in MIL-STD-1797, Figure 4e, where bandwidths below 6.5 rad/sec should be Level 2, at best, so that only Case 11 (Y_C = k/s) should be Level 1. The limits in Figure 4e are known to be extremely stringent, and other data presented in Reference 2 suggest a more reasonable Level 1 limit of approximately 4 rad/sec. An extensive review of a wide variety of aircraft and test data (Reference 21) also supports a relaxation in the bandwidth limits.

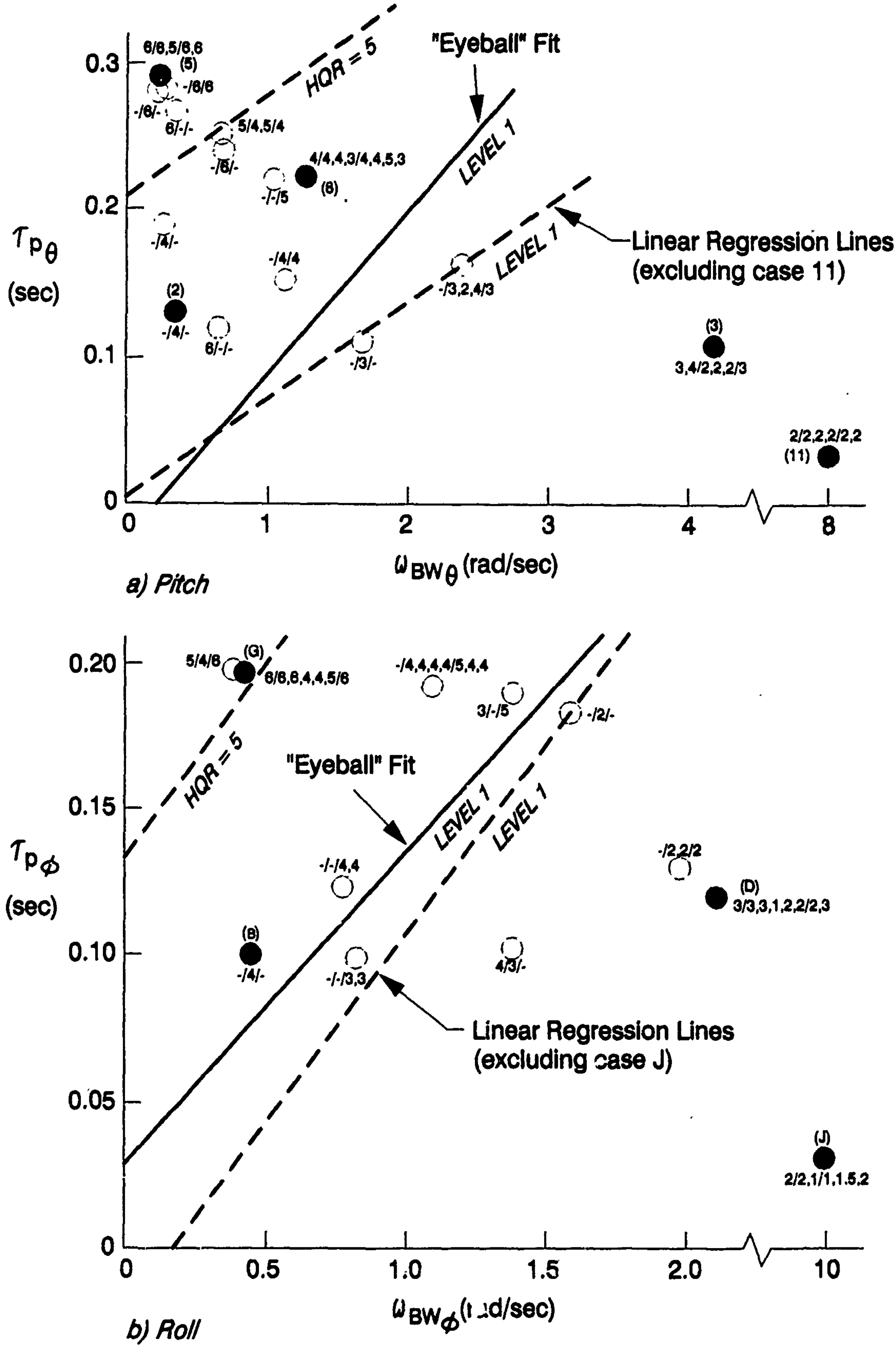


Figure 31. Bandwidth Limits Based on STI Simulation Data
(All Data; Solid Symbols Denote Primary Cases;
HQRs are: Pilot H/Pilot J/Pilot M)

- It is to be expected that the ratings from the single-axis tracking task would be better than those for similar tasks in an actual airplane: in the simulator, the pilot's attention was focused entirely on the axis of control, while a single-axis tracking task in an airplane still requires regulation of the off-axes, e.g., holding wings level during pitch tracking. This is obviously a divided-attention environment to some extent that did not exist in the simulator.

- The Level 1 limits sketched in Figure 31 are straight lines since there is no strong indication of an interaction between bandwidth frequency and phase delay (e.g., the relatively small number of configurations in Figure 31, both pitch and roll, does not show a need for an upper limit on ω_{BW} or on τ_p).

C. LINEAR REGRESSIONS FOR HQR USING BANDWIDTH PARAMETERS

The previous sections of this report have shown varying degrees of success at estimating Handling Qualities Ratings for HUD tracking n one or two axes. Some, such as the OCM, are relatively complicated to apply and require the <u>a priori</u> knowledge of the aircraft model, task description, and pilot parameters. Others, such as single-axis estimates from handling qualities criteria that are combined by the Product Rule, are relatively simple, but not very successful at estimating the HQRs for the fixed-base simulation. An accurate, repeatable, and relatively simple method for estimating Handling Qualities Ratings in one or more axes is still to be found. The bandwidth criteria do not require any more advanced knowledge of the aircraft than the frequency response of pitch (or roll) attitude to control force inputs, are shown in Figure 31 to separate the configurations in terms of HQRs, and, with properly defined boundaries, have been found (Reference 21) to properly estimate flying qualities Levels as well as, and sometimes better than, other alternative criteria. For these reasons, a series of mathematical expressions was developed to determine the relationships between HQR and the parameters of the bandwidth criteria.

Since the straight-line "eyeball" boundaries in Figure 31 appear to separate the Level 1 and 2 data, a linear regression was performed on the HQRs in each axis. Equations for estimated HQR, $\hat{R}_i$ ($i = \theta$ or ϕ), were

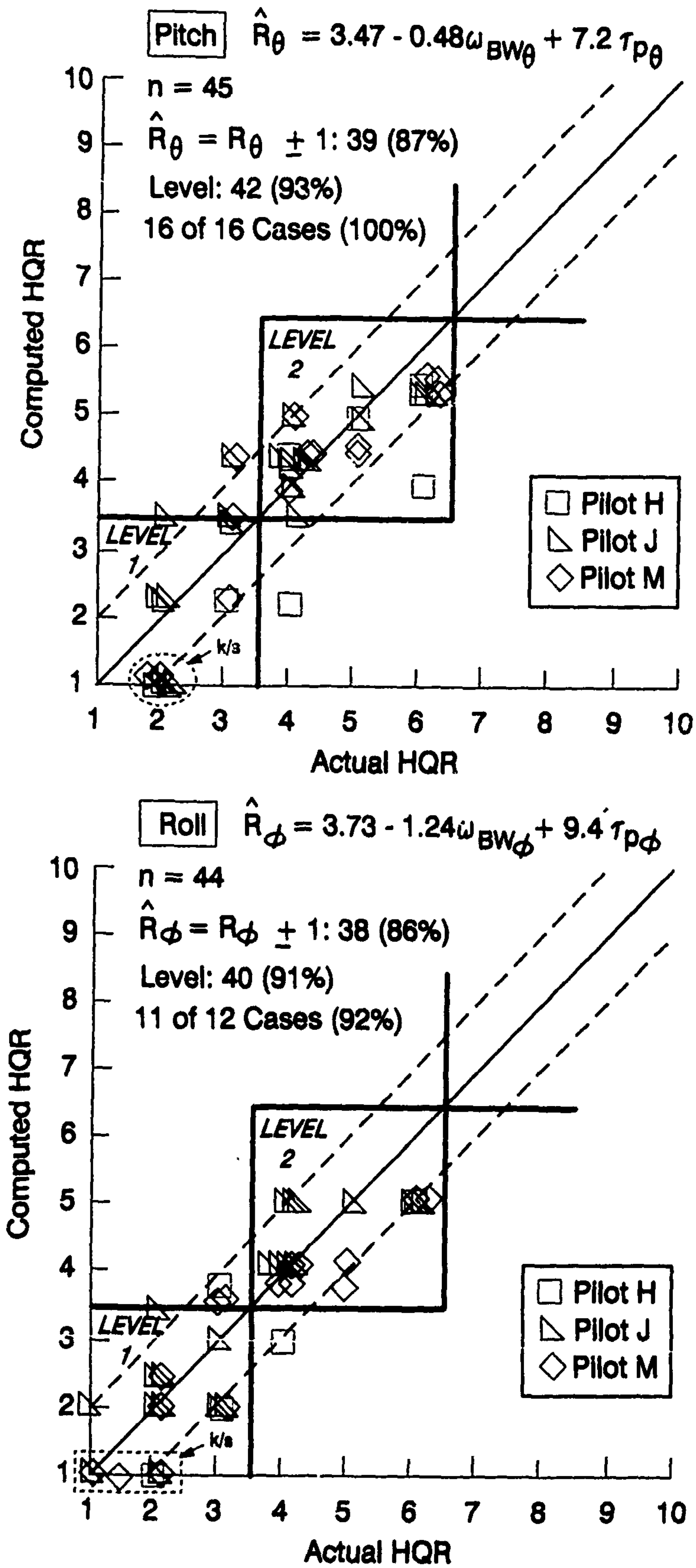


Figure 32. Correlations of Computed HQRs from Single-Axis Linear Regressions with Actual HQRs from STI Fixed-Base Simulation

obtained as linear functions of ω_{BW} and τ_p. Initially, the k/s cases (Case 11 in pitch and J in roll) were included in the determination of the regressions; however, these cases tend to skew the regressions significantly, since their bandwidth frequencies are considerably higher than all the other cases without a correspondingly large improvement in HQR (since the best HQR is 1, and linear regressions are free to assume values between plus and minus infinity). The final regressions used in this analysis were determined with the k/s cases excluded, but these cases will be considered when the efficacy of the regressions is examined.

For pitch, the linear regression fit to the data gives:

$$\hat{R}_\theta = 3.47 - 0.48\ \omega_{BW_\theta} + 7.2\tau_{p_\theta}$$

The number of points, n, is 40, and the correlation coefficient $r^2 = 0.634$, indicating a greater than 99% level of confidence that the parameters are correlated. For roll, the fit is:

$$\hat{R}_\phi = 3.73 - 1.24\ \omega_{BW_\phi} + 9.4\tau_{p_\phi}$$

with $n = 38$ and $r^2 = 0.697$, giving a level of confidence of greater than 99%.

The linear regression lines for HQR = 3.5 (Level 1 limit) and 5 are shown on Figure 31. These simple linear equations are very effective at separating the configurations in both pitch and roll, indicating their potential as estimators of HQR for other aircraft models.

As a first check of the linear regressions, estimated HQRs for all of the Figure 31 cases were calculated and plotted against the actual ratings. Figure 32 shows the correlations for the computed and actual HQRs for all ratings, all cases (including the k/s cases). Several measures of the success rates for the regressions are noted on each plot in Figure 32: 1) the total number of computed HQRs, $\hat{R}_i$, that are within ±1 point of the actual ratings (39 out of 45 or 87% for pitch, 38 out of 44 or 86% for roll); 2) the number of computed HQRs that lie within the same Level as the actual HQR (42 out of 45 or 93% for pitch and 40 out of 44 or 91% for roll); and 3) the most important measure of success: the number of cases that are computed to be in the correct Level overall,

based on average HQRs for each case (16 out of 16 or 100% for pitch, 11 out of 12 or 92% for roll).

It should be noted that the equations above can give estimated HQRs of less than 1 and greater than 10; for example, the computed HQRs for the k/s cases are -0.1 and -8.4 in pitch and roll, respectively. Since such estimates are clearly unrealistic, computed HQRs less than 1 are automatically assumed to be 1, and HQRs greater than 10 are set to 10.

D. REVISED PRODUCT RULE

The results of the STI simulation provide a new data base for re-examining the classical Product Rule of Reference 7. The original formula, applied in Figures 29 and 30, is effective in correlating the multiple-axis HQRs. Since the original formula was developed using pilot ratings based on the old Cooper scale, and not the Cooper-Harper scale, a hyperbolic regression was run on the simulation data to determine new coefficients for the equation (a hyperbolic form was used since the Product Rule equation is in the form of a general hyperbola). Figure 33 repeats the HQR crossplots of Figure 29 with the classical Product Rule (long dashed lines) and revised Product Rule (solid lines) regressions shown for iso-rating lines of 3.5 and 6.5. The revised hyperbolic Product Rule has slightly different coefficients (noted on Figure 33), and is slightly more conservative than the original formula, but in general, the differences are not significant.

Both hyperbolic formulas have some serious shortcomings: if a rating in one axis is extremely good (e.g., 1), the classical Product Rule predicts the two-axis rating to be better than the single-axis ratings. For example, suppose the single-axis HQRs are 1 (pitch) and 4 (roll). Logically, one would expect the dual-axis case to be Level 2, with an overall HQR of 4 or worse. The classical Product Rule, however, predicts an HQR for the dual-axis case of 3.49, or Level 1. In fact, the classical Product Rule will <u>always</u> predict better multi-axis ratings if one axis receives an HQR of 1.7 or better (i.e., as long as $|(HQR - 10)| > 8.3$). This can be observed in Figure 33 at the ends of the iso-pilot rating lines. The revised hyperbolic formula is somewhat better; for the same

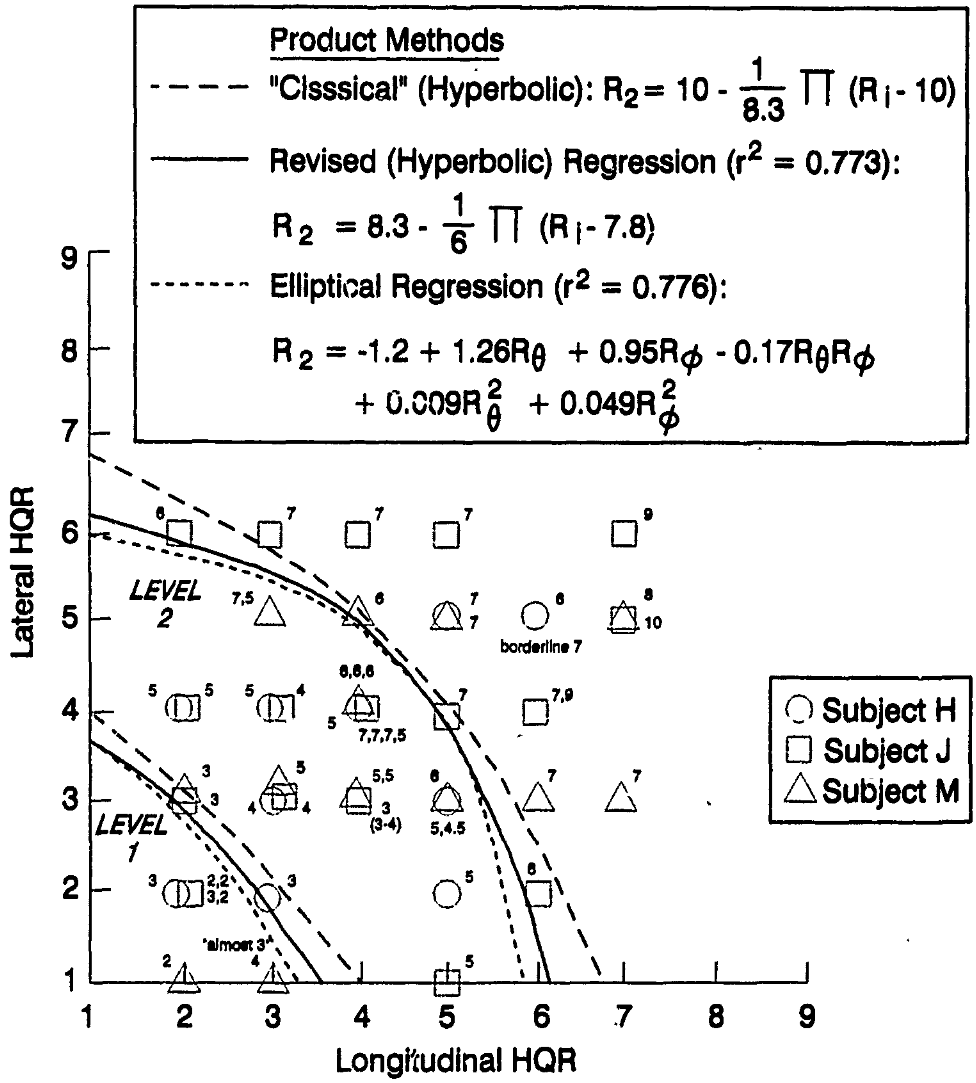


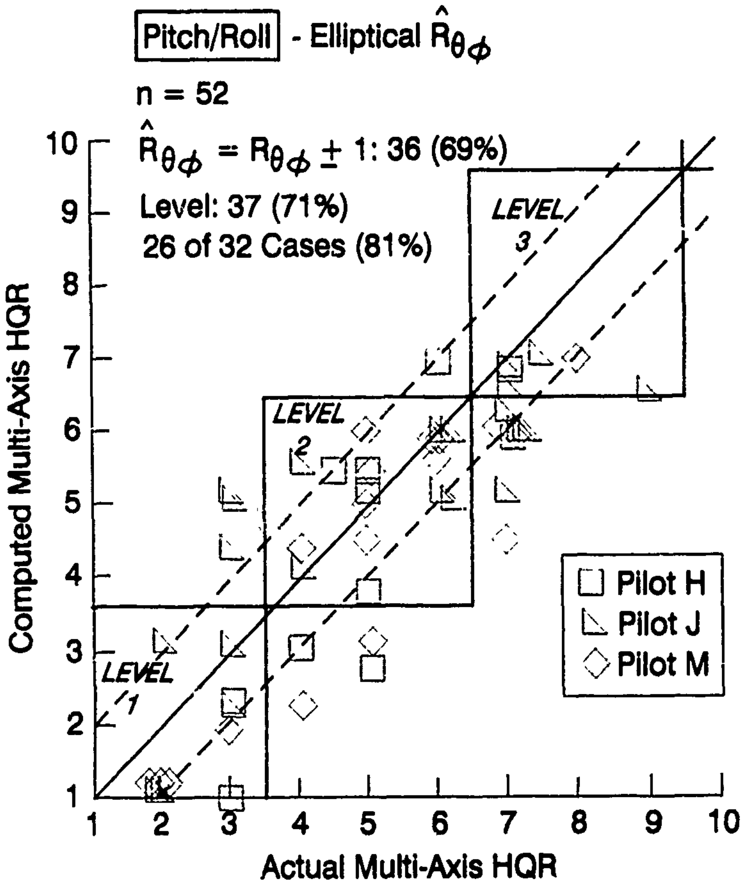
Figure 33. Product Rule Regressions for STI Simulation Data

example, with HQRs of 1 and 4, this formula predicts a multi-axis HQR of 3.99. Both equations have problems if ratings in both axes are good (e.g., 1 and 1 or 1 and 2, etc.).

The fundamental problem with the hyperbolic Product Rule expressions is the lack of recognition of the limits of the HQR scale. The HQR scale can have values only between 1 and 10, while hyperbolic equations are not limited. An alternative expression can be determined by applying a general formula that is elliptical, rather than hyperbolic, in structure, i.e, that can bound both pitch and roll HQRs between 1 and 10. A regression fit to the STI simulation data was performed for such an expression, with the results shown in Figure 33 (short dashed lines). While this formula is no more successful than the revised hyperbolic Product Rule in correlating pilot ratings, it does not suffer from the shortcomings of the hyperbolic expressions. It is, however, more complicated (products and squares of HQRs are included), and cannot be generalized to more than two axes.

As a check of the effectiveness of the elliptical Product Rule equation in Figure 33, dual-axis HQRs were computed for the STI simulation and compared with the actual HQRs. Rather than using the actual single-axis ratings from the simulation to begin with, however, the single-axis ratings from the simulation were first estimated from the bandwidth regressions, and then combined through the Product Rule. This is, therefore, a verification not only of the Product Rule, but of the efficacy of the bandwidth regressions for estimating pilot ratings.

Figure 34 shows the correlation between the computed HQRs and the actual multi-axis ratings from the STI simulation. For this figure, if a single-axis rating were computed to be less than 1 (e.g., the k/s cases), it was defined as 1 before applying the elliptical Product Rule method, and if the overall multi-axis HQR were computed to be less than 1 (e.g., k/s in pitch and roll), it was likewise redefined to be 1 for the plot. Based on Figure 34, these regression formulas are very accurate: 36 of the 52 HQRs (including all cases with k/s in one or both axes) are computed to be within ±1 of the actual rating; 36 of the 52 HQRs are in the correct Level; and overall, the method correctly computed the flying qualities



Levels for 6 Multi-Axis Cases are not Predicted Correctly:

CASE	EST. HQR	ACTUAL HQR (H/J/M)
2B	5.9	-/7/-
4G	6.2	-/7/-
5D	5.9	-/-/7
5I	7.0	6/-/-
8F	5.2	-/3/-
11C	2.8	5/-/-

Figure 34. Correlations of Computed HQRs with Actual Multi-Axis HQ
from STI Fixed-Base Simulation

Levels for 26 of the 32 multi-axis cases, for a success rate of 81%. This is remarkably good considering the simplifications involved.

The bottom of Figure 34 lists the 6 "failures" of this method, all of which have several common characteristics: all received only one rating; in all cases except the last (11C), a one-point difference in rating would result in correctly predicted Levels, and in all but one case (8F) a one-point difference in the estimated HQR would result in correlation. This is still extremely good verification of the procedures applied in Figure 34.

E. APPLICATION OF THE REGRESSIONS AND REVISED PRODUCT RULE

The general procedures for estimating dual-axis HQRs, given the bandwidth parameters (frequency and phase delay) for the pitch and roll models, are as follows:

1. Compute the estimated single-axis HQR for pitch:

$$\hat{R}_\theta = 3.47 - 0.48\,\omega_{BW_\theta} + 7.2\,\tau_{p_\theta}$$

subject to the limits $1 \le \hat{R}_\theta \le 10$;

2. Compute the estimated single-axis HQR for roll:

$$\hat{R}_\phi = 3.73 - 1.24\,\omega_{BW_\phi} + 9.4\,\tau_{p_\phi}$$

subject to the limits $1 \le \hat{R}_\phi \le 10$;

3. Compute the estimated multi-axis HQR for pitch and roll:

$$\hat{R}_{\theta\phi} = -1.2 + 1.26\hat{R}_\theta + 0.95\,\hat{R}_\phi - 0.17\hat{R}_\theta\hat{R}_\phi + 0.0092\hat{R}_\theta^2 + 0.049\,\hat{R}_\phi^2$$

subject to the limits $1 \le \hat{R}_{\theta\phi} \le 10$;

F. HQR ESTIMATES FOR THE MOVING-BASE SIMULATION

Estimated flying qualities (i.e., HQRS) for the LAMARS configurations were made using the methods described above, and the OCM. All other criteria were either poor correlators of pilot opinion for the fixed-base data, or not applicable to the multiple-axis situation.

Table 10 lists the single- and dual-axis HQR estimates for the LAMARS cases. Since the OCM estimates for the fixed-base cases were generally very good (with the exception of the lightly-damped pitch Cases 5 and 6), the numbers in Table 12 are identical to the earlier OCM estimates. All multiple-axis combinations of Cases 5 and 6 have been dropped from further consideration in recognition of the OCM's failure to properly estimate these cases. Bandwidth/Product Rule estimates are given, however, for all cases, even though the formulas have some difficulty with cases that have extremely high bandwidth frequencies.

TABLE 10. ESTIMATED HQRS FOR LAMARS EVALUATION CONFIGURATIONS

HQRs Are: $\hat{R}$(Bandwidth/Product Rule)

<$\hat{R}$(OCM)>

ROLL				$1/T_R$ (rad/sec)	100	0.5	0.5	4.0
				τ (sec)	0.0	0.067	0.20	0.067
PITCH				LAMARS Case I.D.	A	B	C	H
ζ_{sp} (–)	ω_{sp} (rad/sec)	τ (sec)	LAMARS Case I.D.	Single-Axis Est.	1.0 <1.9>	4.0 <4.8>	5.0 <6.0>	1.8 <2.9>
4.526	11.18	0.0	1	1.0 <1.9>	1.0 <3.5>	4.0 <5.5>	5.2 <6.5>	1.7 <3.9>
0.80	5.0	0.033	2	1.6 <2.2>	1.5 <3.5>	4.3 <5.4>	5.5 <6.5>	2.2 <3.9>
0.80	5.0	0.20	4	4.2 <2.7>	4.5 <3.7>	6.0 <5.5>	6.6 <6.5>	4.8 <4.1>
0.18	5.0	0.033	5	4.0 <–>	4.3 <–>	5.8 <–>	6.5 <–>	4.6 <–>
0.18	5.0	0.20	6	5.3 <–>	5.8 <–>	6.7 <–>	7.2 <–>	6.0 <–>

Transfer Function Forms:

$$\text{Pitch:}\quad \frac{\theta}{\theta_c} = \frac{\omega_{sp}^2/1.25\,(s + 1.25)e^{-\tau s}}{s[s^2 + 2\zeta_{sp}\,\omega_{sp}s + \omega_{sp}^2]}$$

$$\text{Roll:}\quad \frac{\phi}{\phi_c} = \frac{1/T_R\; e^{-\tau s}}{s(s + 1/T_R)}$$

SECTION VI

RESULTS OF MOVING-BASE SIMULATION

A. ADDITIONS TO MATRIX FOR MOVING-BASE SIMULATION

The fixed-base simulation conducted at Systems Technology, Inc., provided verification of the procedures, tasks, and configurations that were planned for the formal moving-base simulation. The facility for this simulation was the Large Amplitude Multimode Aerospace Research Simulator (LAMARS) at Wright-Patterson AFB, Ohio. The more complete facilities of the LAMARS provided for expansion of the simulation matrix to include several additional tasks that were not (or could not be) evaluated on the STI simulator. The most significant of these, the details and results of which are reported in this section, were as follows:

- Addition of a third control task: A more complete Head-Up Display (HUD) allowed the projection of additional error signals for the pilot to control. A pseudo-airspeed error was displayed with a vertical pointer and the pilots were required to null this error (through a simple transfer function model for airspeed) using the left-hand throttle controller. The very high workload associated with this task, in combination with the pitch and roll tasks, required that certain simplifications and reductions in the forcing function be made, and that the task be interpreted in a different form.

- Addition of a non-control sidetask: A flat-panel screen in the cockpit was used to generate a sidetask that required the pilots to follow a numerical sequence of boxes using a finger-actuated cursor. This task demanded considerable head-down operation, and there were difficulties with training time for using the throttle-mounted cursor control, so this task was later abandoned.

- Evaluations for a low-altitude visual task: Several ground-referenced flying tasks were added as an alternative to the HUD tracking to determine if there were any significant task effects. The original plans called for simulating offset landings, but early runs for this task showed that the pilot ratings were significantly affected by both pitch and roll dynamics. Instead, tasks that involved wings-level dives and climbs (comparable to single-axis pitch tracking), constant-altitude turns (roll tracking), and combined maneuvers (pitch/roll tracking) were used.

- Comparisons with fixed-base simulation: The results, in terms of both qualitative HQRs and quantitative describing functions, could be compared with the STI fixed-base simulation data. In addition, two pilots flew several cases on the LAMARS in fixed-base mode, providing further fixed- versus moving-base comparison data.

- Expansion of the pilot population: Three pilots flew the STI simulation, and one of these for only a few evaluations. The increased time allotted for the LAMARS simulation also allowed for an expanded pilot population of six pilots. This population ranged in experience and background from a general-aviation pilot with limited simulator experience to two recent Air Force Test Pilot School graduates, and included two of the three evaluators from the STI simulation (Pilots H and M) for continuity. Background information on all six of the LAMARS evaluation pilots is provided in Appendix B of this report.

The remainder of this section reviews the more significant results from the moving-base simulation, including inter-pilot differences; performance (describing function data) for all pilots for the primary pitch and roll configurations, single-axis; effects of dual-axis tracking in terms of pilot opinion and performance; effects of adding a throttle and head-down managerial sidetask; results from the series of visual (terrain-board-referenced) tasks; evaluation of the HQR differences between the fixed-base and moving-base simulations; and finally, a summary comparison of the estimated flying qualities from the previous section with the tracking and terrain-board data.

Full documentation of the LAMARS moving-base simulation and results is given in Appendix B of this report.

B. REVIEW OF RESULTS FOR HUD TRACKING

While much of the simulation time was focused on single- and dual-axis HUD tracking with the primary pitch and roll cases given in Table 2 (Section II), several additional configurations were evaluated during the course of the program. The results for these additional cases will be included as appropriate throughout this section to augment the primary data base.

With the addition of a third axis to control (airspeed), the matrix of permutations grew rapidly; evaluations were now necessary for pitch, roll, and airspeed alone; pitch/roll, pitch/airspeed, and roll/airspeed; and pitch/roll/airspeed, for the five pitch, four roll, and (originally) three airspeed transfer function models (as documented in Appendix B). It was discovered early in the simulation, however, that with the already high-workload pitch and roll tasks, <u>any</u> airspeed transfer-function model was difficult to control unless both the amplitude and bandwidth of the forcing function in airspeed were reduced considerably. Once these reductions were made, it then made little difference which transfer-function model was used, since the overall airspeed response was slow for all of them. It was decided at this point that the objectives of adding the third axis of control could be met by using only one transfer-function model for all runs, and the airspeed response (and throttle command sensitivity) were fixed for the remainder of the simulation.

No pilot ratings were generated for HUD tracking with the non-control, head-down sidetask. With the high workload of the primary task, the requirement for the pilots to look away from the HUD for extended periods was simply too harsh. More is said about this in a later subsection.

The pilot ratings for the primary pitch and roll configurations are summarized in Table 11. The format of the ratings in this table is different from that used for the fixed-base results; since there were six pilots and many repeat runs, the number of pilot ratings is too great to attempt to list actual HQRs. Instead, Table 11 shows the total number of ratings (all pilots), the average HQR, and the lowest and highest ratings received for each configuration. Specific HQRs are given in Appendix B. The relatively small spread between minimum and maximum HQR for most cases in Table 11 reflects the consistent inter-pilot ratings obtained in the moving-base simulation. The few exceptions, e.g., combined-axis Case 2C, where the HQRs ranged from 4 to 8, tend to reflect the difficulties of one or two pilots in certain of the roll configurations, as is shown below.

The priorities between overall tasks (HUD tracking and low-level maneuvering) were divided between pilots, with three (Pilots B, M, and V) acting as primary pilots on the HUD tasks, while the other three (Pilots

TABLE 11. HQRS FOR PRIMARY EVALUATION CONFIGURATIONS FROM MOVING-BASE SIMULATION (HUD TRACKING)

Format: Number of Ratings: Avg. HQR (1-6 Pilots)
(Min, Max. HQR)

			ROLL	$1/T_R$ (rad/sec)	100	0.5	0.5	4.0
			ROLL	τ (sec)	0.0	0.067	0.20	0.067
PITCH				LAMARS Case I.D.	A	B	C	H
ζ_{sp} (–)	ω_{sp} (rad/sec)	τ (sec)	LAMARS Case I.D.	Single-Axis HQRs	9:2.0 (1,3)	9:4.6 (3,6)	12:5.4 (4,8)	17:2.3 (1,4)
4.526	11.18	0.0	1	14:2.1 (1.5,3)	9:3.3 (2,5)	1:7.0 (–)	3:6.5 (5.5,7)	4:4.2 (3,5)
0.80	5.0	0.033	2	17:2.6 (2,4)	5:3.0 (2,4)	5:5.6 (5,7)	6:6.5 (4,8)	13:3.8 (3,6)
0.80	5.0	0.20	4	17:3.9 (3,5)	3:4.1 (4,5.5)	1:5.5 (–)	4:5.8 (5,7.5)	11:4.6 (3,6)
0.18	5.0	0.033	5	8:5.1 (5,6)	1:5.0 (–)	3:7.0 (6,8)	2:6.5 (6,7)	4:5.6 (5,6)
0.18	5.0	0.20	6	7:6.0 (5,7)	1:7.0 (–)	2:7.5 (7,8)	1:7.0 (–)	5:6.3 (5,8)

Transfer Function Forms:

Pitch: $$\frac{\theta}{\theta_c} = \frac{\omega_{sp}^2/1.25\,(s + 1.25)e^{-\tau s}}{s[s^2 + 2\zeta_{sp}\,\omega_{sp} s + \omega_{sp}^2]}$$

Roll: $$\frac{\phi}{\phi_c} = \frac{1/T_R\; e^{-\tau s}}{s(s + 1/T_R)}$$

H, S, and W) focused on the terrain-board tasks. All pilots, however, flew some HUD cases, but because the terrain-board tasks were added late in the simulation, Pilots M and V did not fly any evaluations for these tasks.

As with the fixed-base simulation, the first test of validity for the overall simulation is to examine the raw pilot ratings for signs of inter-pilot variations. Since there are six pilots, proper analysis of the ratings requires crossplotting all HQRs for each pilot against each other pilot for corresponding cases that were flown by both pilots. For the fixed-base simulation, with only three pilots, three plots were sufficient. Here, however, a total of fifteen plots are required, Figure 35. These plots include all HUD tracking cases -- pitch, roll, airspeed, and all combinations -- that were flown by more than one pilot. Since many pilots flew repeat runs, the average ratings for any one case are used.

With such a large pilot population, it is not surprising to find some pilot-to-pilot variations in HQRs. Examination of the plots in Figure 35 reveals some consistent rating differences between pilots: 1) Pilots B and H tended to assign better (lower) HQRs than all other pilots 2) Pilots S, V, and W were generally harsher raters (gave higher ratings) than the others (this is especially evident in the last set of plots in Figure 35, where the HQRs for these three pilots are compared). For Pilots S and W this may in part be a reflection of the relatively short exposure these pilots received to the HUD task. In addition, Pilot W tended to select very light stick forces and thus encountered PIOs more frequently than the others, and Pilot V expressed great difficulty with controlling the more degraded roll cases 3) In general, the inter-pilot rating variations are smallest for the pitch cases (circles) and greatest for the roll (squares) and pitch/roll (diamonds) cases. (These observations are more apparent in the summary plots of Appendix B, where the HQRs are plotted case-by-case.) The overriding conclusion from the plots in Figure 35 is that any detailed analysis of the HUD tracking results will require a careful accounting of the individual pilot rating differences.

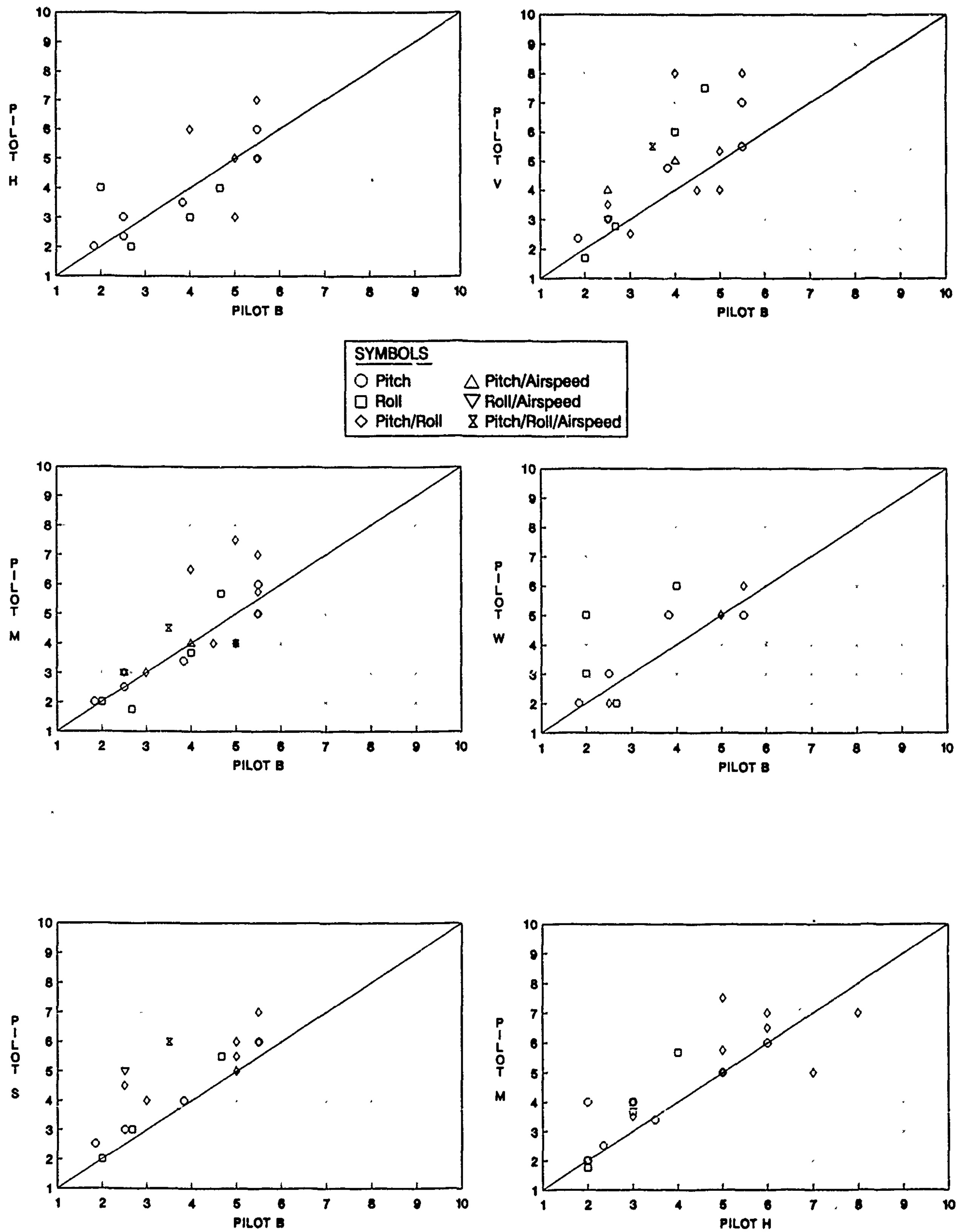


Figure 35. Crossplots of Pilot Ratings for Corresponding Cases in HUD Tracking (Average Ratings are Used for Repeat Runs)

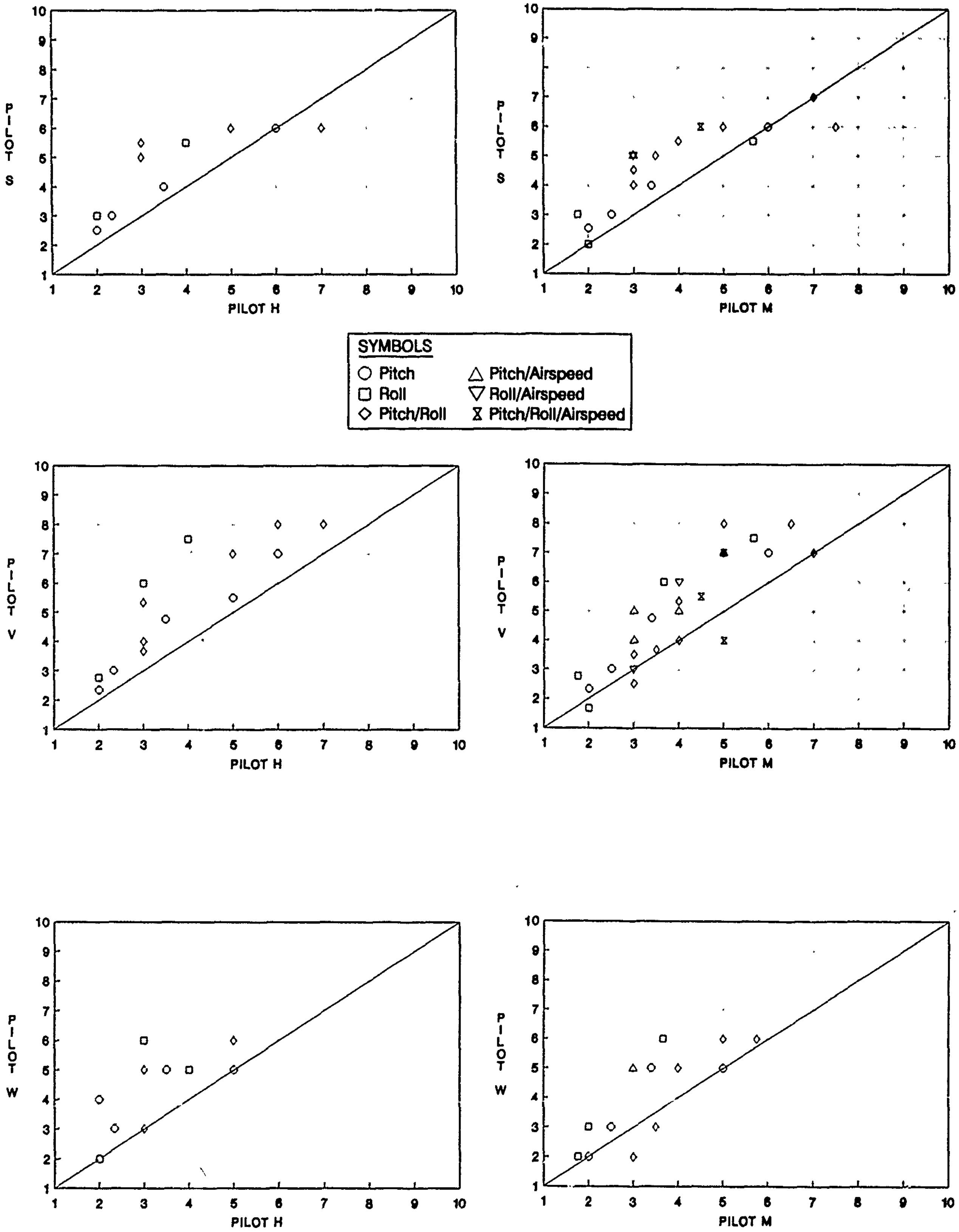


Figure 35. (Continued)

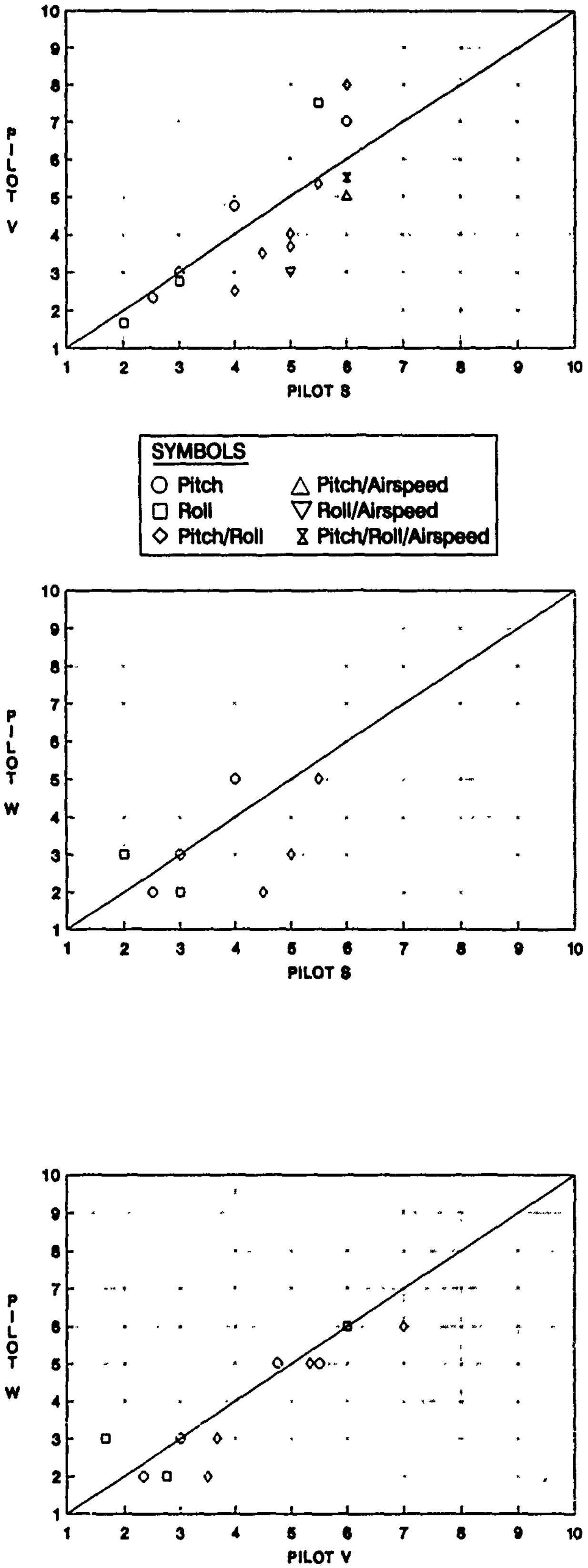


Figure 35. (Concluded)

As with the fixed-base simulation, measures of pilot behavior were recorded during all of the HUD tracking runs (a printout of these measures was available immediately after every run, allowing a quick verification of the results, and the data were stored and later transferred to floppy disks for final analysis). The describing-function data are very similar to the data obtained from fixed-base simulation, and verify that compensatory tracking occurred. Example plots and extracted pilot models are presented in Appendix C of this report.

A summary plot of several pilot performance measures is shown in Figure 36 for the five pitch and four roll primary cases. These data are all from single-axis cases. All cases were run at least twice before an HQR was assigned, and it was not uncommon for the pilot to make a third run. Each symbol in Figure 36 represents an average value for each pilot for the last run in a particular sequence (spreads in the values have been omitted for clarity). For this plot it has been assumed that the last run represents the best performance possible, although this is not necessarily always the case. The plot shows normalized performance, $\bar{e}/\sigma_c$; crossover frequency, ω_c; phase margin, Φ_M; and HQR. Normalized performance is an indication of how well the pilot was able to reduce the forcing function error ($\bar{e}/\sigma_c$ = 1.0 indicates no error reduction). The trends for increasing error and decreasing crossover frequency as HQRs increase are consistent for all pilots. In addition, the k/s cases (1 in pitch, A in roll) were, overall, the best in terms of both performance and pilot ratings, as would be expected for compensatory tracking (Reference 16).

Figure 36 suggests that, in terms of pilot performance, pitch Cases 1 (k/s) and 2 (the best "airplane" dynamics) were very similar, as were roll Cases A and H. These cases were used interchangeably throughout the simulation whenever a good baseline configuration was desired in one axis. Figure 36 also shows that Pilot V tended to assign the highest HQRs for the single-axis configurations; his errors, however, were also generally higher, so the higher HQRs are not surprising, and his relative ordering of the cases (best to worst) was consistent with all the other pilots.

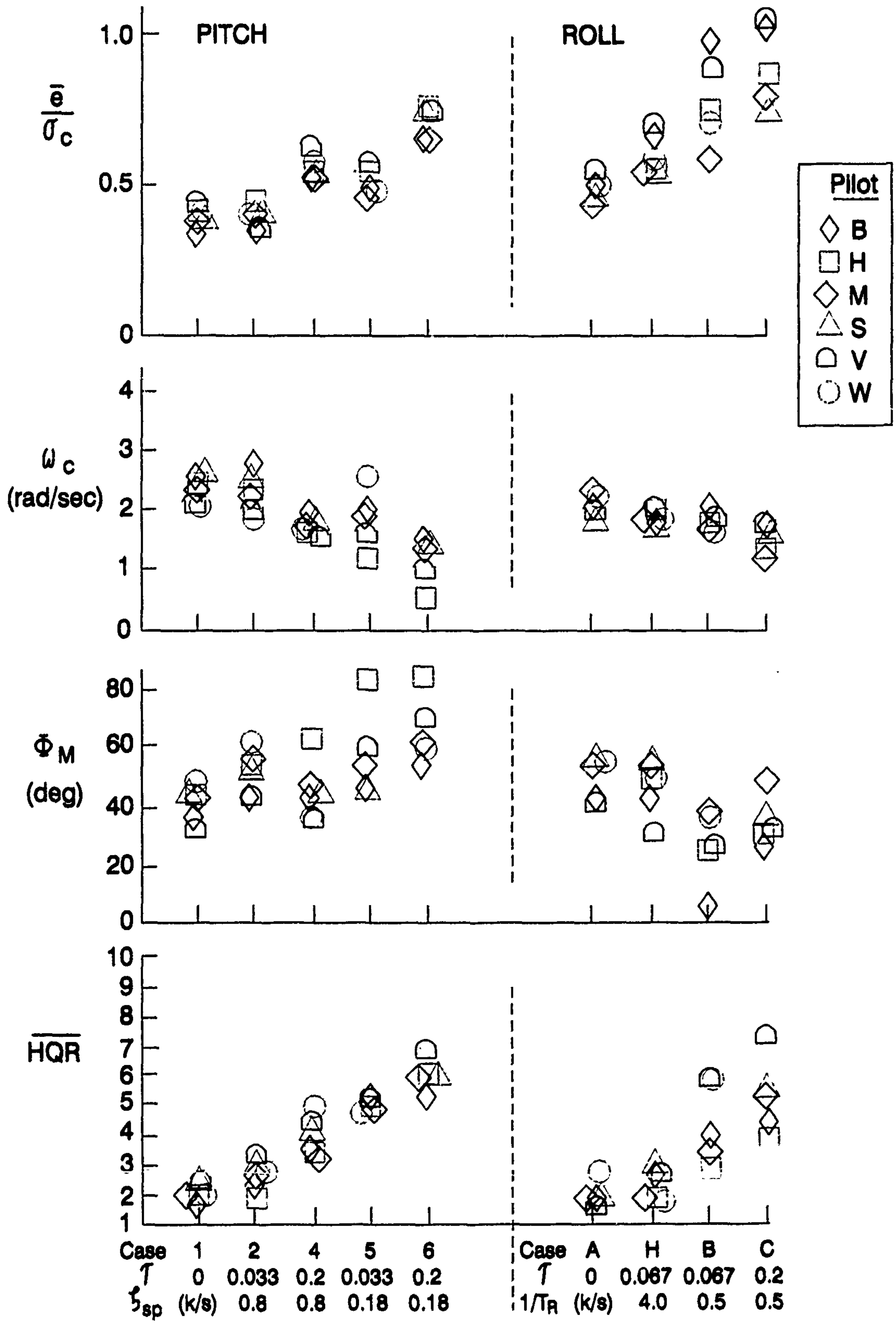


Figure 36. Summary of Pilot Performance for Primary Cases from Moving-Base Simulation (Averages for Last-Run Data)

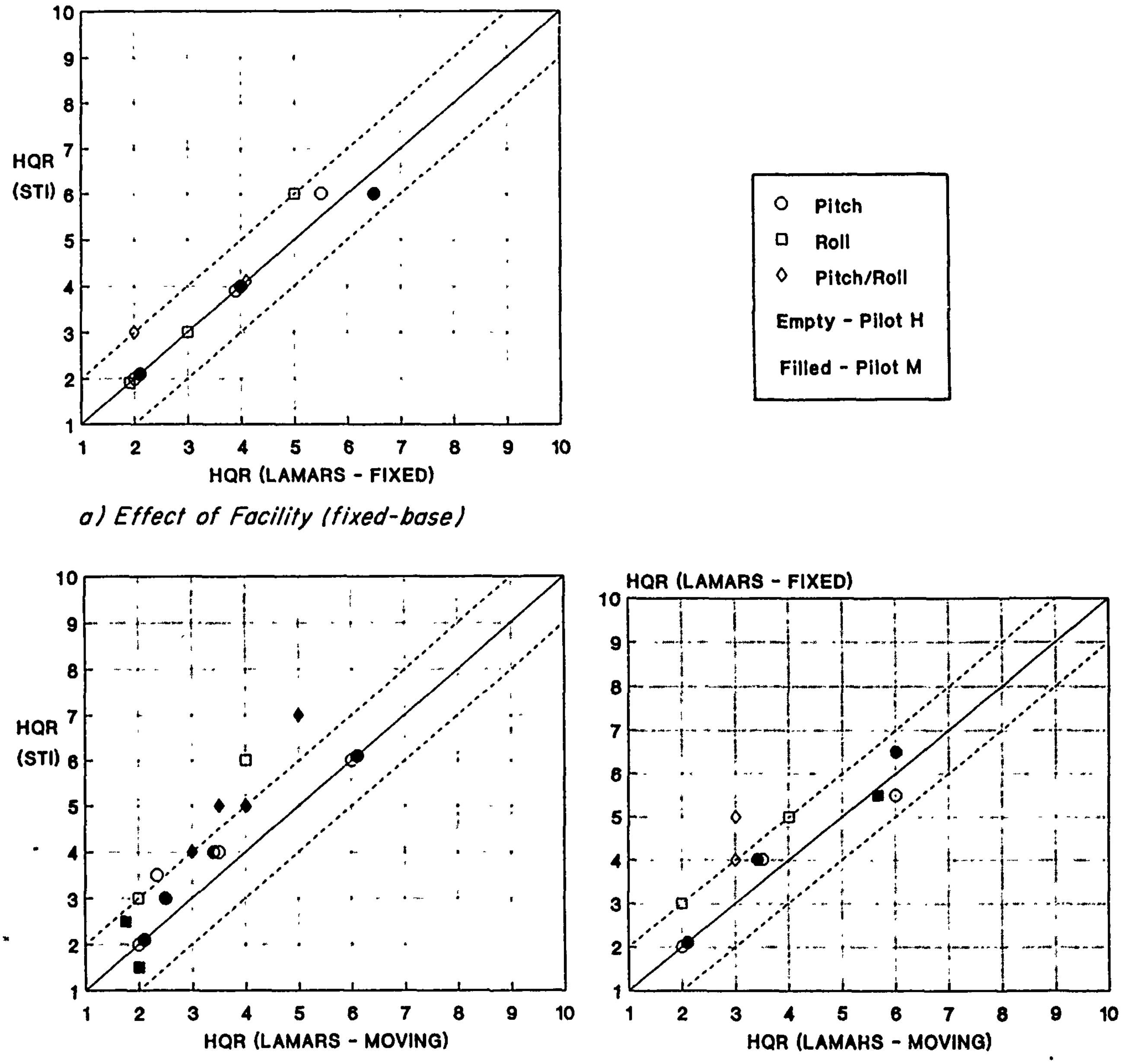
C. COMPARISON OF FIXED-BASE AND MOVING-BASE PILOT RATINGS

Except for slight differences in control stick dynamics, the primary cases evaluated on the moving-base simulator were identical to those evaluated fixed-base on the STI simulator. A comparison of HQRs obtained for these cases will reveal if there were any differences due to motion. In addition, of course, it is possible that additional differences exist due simply to the very different facilities, or to the mechanization of the configurations (analog vs. digital computers, etc.). As a check of these second-order effects, a brief mini-matrix (one session) was conducted on the LAMARS with the simulator in fixed-base mode, using Pilots H and M, who were also evaluators on the STI simulation.

Figure 37a shows a crossplot of HQRs for cases that were flown on both the STI fixed-base simulator and the LAMARS in fixed-base mode (all ratings are averages for each pilot, each case). There are no obvious differences for the few data points plotted.

A more noticeable trend occurs when motion is added, Figure 37b, with a relatively consistent offset in HQR of about one point, i.e., the LAMARS (moving-base) ratings are about one rating better than the STI (fixed-base) ratings. Since the ratings for both simulators fixed-base, Figure 37a, showed no such differences, it may be concluded that addition of motion improved the HQRs about one point. This is as expected, since motion cues provide some information to the pilot that is otherwise missing in the display -- i.e., on an error-only display, it is difficult for the pilot to discern whether unwanted errors are due to the forcing function driving the display, or to the pilot's inputs to the aircraft itself. With motion, the pilot has direct feedback of the aircraft's response and can better sort out the source of the displayed errors.

For the LAMARS fixed- versus moving-base, Figure 37, the story is not quite as clear. There are, however, fewer ratings here than in Figure 37b, and of the 11 points shown, 7 received better ratings with the motion on, while worse ratings were given to only two. So the trends here support those noted for Figure 37b.



a) Effect of Facility (fixed-base)

b) Effect of Facility and Motion

c) Effect of Motion (LAMARS)

Figure 37. Effects of Simulation Facility and Motion on HQRs (HUD Tracking; STI Simulation was Fixed-Base)

D. COMPARISON OF SINGLE- AND DUAL-AXIS HUD TRACKING RATINGS WITH ESTIMATES

Estimated HQRs for the primary pitch and roll cases on the moving-base simulation were developed in Section IV (Table 10). The methods applied were the Optimal Control Model (OCM), and a combination of mathematical regressions for single-axis HQRs based on the bandwidth parameters and Product Rule expressions for combining these single-axis estimates into multi-axis HQRs.

The effectiveness of these estimates is illustrated by Figure 38, where the estimates from Table 10 have been crossplotted against the actual average HQRs from Table 11. For the five pitch cases (Figure 38a), two of the OCM estimates are not shown since it was determined earlier (Section III) that the OCM had problems with low-damped dynamics. For the other three cases, the OCM correctly predicted the flying quality Levels for two (the estimated HQR for Case 4 was 2.7, while the actual average HQR was 3.9). The bandwidth linear regression estimates were successful for all five pitch cases.

Both the OCM and the bandwidth regressions correctly predicted the Levels for all four roll cases (Figure 38b). The OCM is capable of dealing with the more conventional roll-axis dynamics, where some pilot lead is required to achieve k/s-like pilot-vehicle dynamics around the crossover frequency.

For the multi-axis case, Figure 38c, all combinations with the low-damped pitch Cases 5 and 6 have been omitted; of the remaining 12 cases, the Levels for 11 are predicted correctly. The single exception is Case 1B, which was evaluated only once, by Pilot V, who assigned this case a 7, compared to an estimated HQR of 5.5. As noted above, Pilot V tended to assigned higher (in number) ratings than the majority of the other pilots for the degraded roll configurations, so it is likely that a lower average HQR would have been obtained if more than one pilot had evaluated Case 1B.

Fourteen of the 20 total pitch-roll cases were predicted within their correct Levels by the bandwidth/Product Rule regressions (Figure 38c).

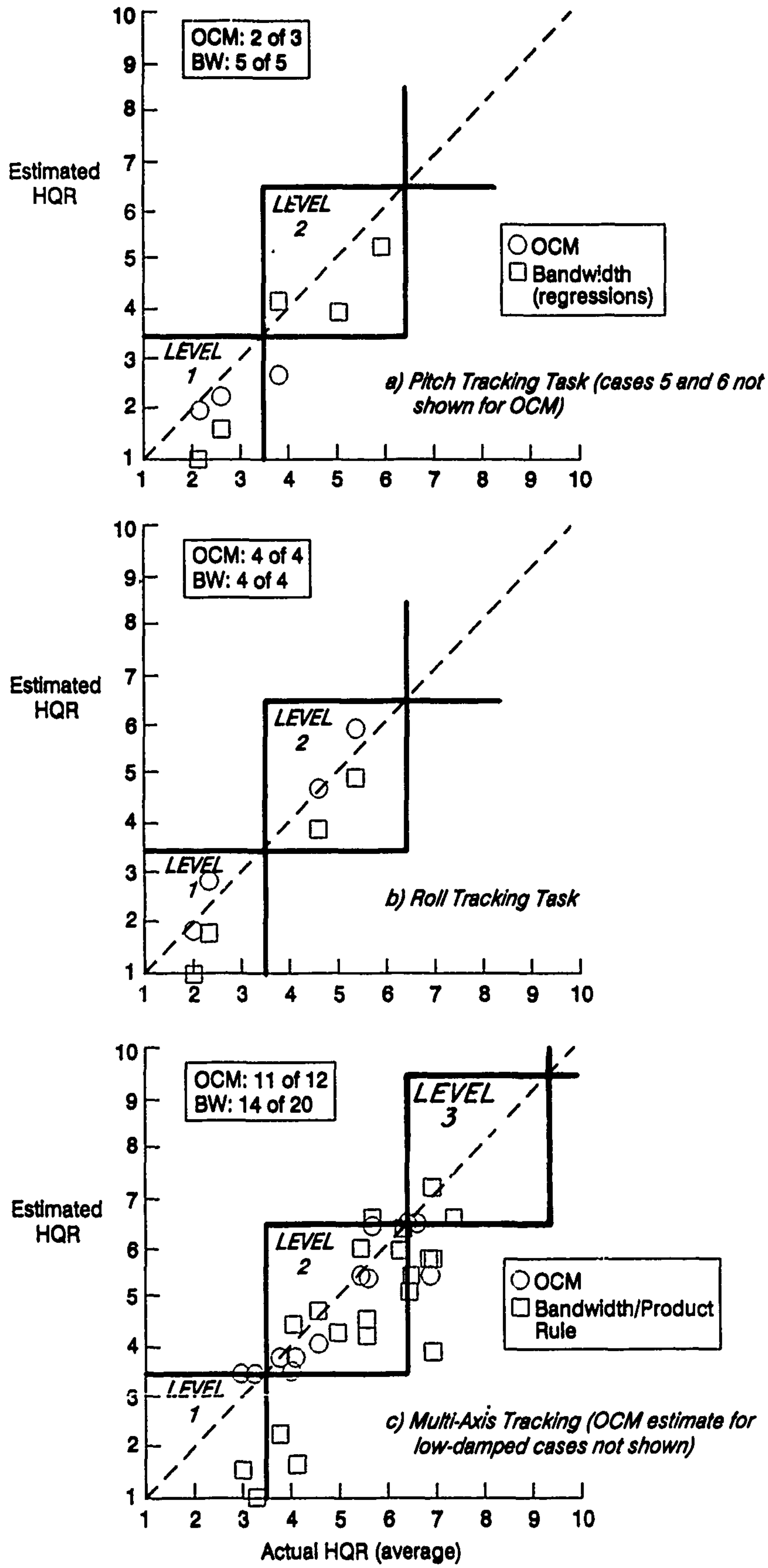


Figure 38. Crossplot of Average Pilot Ratings from Moving-Base Simulation with Estimated Ratings from Table 9

The following list shows the six cases that were not correctly predicted, including the actual HQRs that comprise the averages:

CASE	EST. HQR	AVG. HQR	ACTUAL RATINGS (PILOT)
1B	5.8	7.0	7(V)
1H	1.7	4.2	5(B), 3(H), 5(S), 4(V)
2H	2.2	3.8	3.5, 5, 4.5(B); 3(H); 3.5, 3, 4(M); 6, 4(S); 4, 4, 3(V); 3(W)
4C	6.6	5.8	5(B), 5(H), 7.5(M), 6(S)
5B	5.8	7.0	6, 7(M); 8(V)
6A	5.8	7.0	7(M)

One of these cases is Case 1B, discussed above; Case 6A is similar in that only one HQR was obtained; for Case 5B, there are only three ratings, and for Case 4C, there are four, but the estimated HQR of 6.6 is very close to being Level 2 (6.5) instead. For Case 2H, where the average of 3.8 is barely Level 2, there are thirteen ratings, but four of them are Level 1 and two are ratings of 3.5, suggesting these pilots could not decide if this case was Level 1 or 2. Finally, Case 1H is estimated optimistically because of the known biases in the linear regressions developed in Section V: both Case 1 and Case H are estimated to have very good HQRs, so the combination is estimated to be good as well. (It must be noted here as well that Figure 37 showed an improvement in HQR for motion compared to no-motion operations, and the regressions applied here were developed from the fixed-base simulation results of Appendix A. It is possible that correlation would improve somewhat if this were taken into account in the regressions.)

With these few exceptions, the mathematical regression approach to estimating dual-axis HQRs is promisingly effective. At this point, of course, further refinement is possible by regenerating the regression formulas using the moving-base simulation data. This is done in Section VII of this report.

E. EVALUATION OF PILOT PERFORMANCE FOR DIVIDED-ATTENTION OPERATIONS

In Section IV, a method for evaluating the pilots' behavior in conditions of divided attention (as occurs in two-axis tracking) was introduced. This involved the plotting of ratios of crossover frequency for the dual-axis/single-axis cases in pitch and roll, and is elaborated on in Figure 25 in Section IV. This method is applied here as well for the six pilots. The objective is to observe the trends in crossover frequency when the pilot changes for single-axis to dual-axis tracking: no change in crossover frequency in either axis suggests the pilot is unaffected by additional tasks (i.e., division of attention between axes), while a uniform decrease in both axes would suggest an even division of attention, etc.

Figure 39 shows the crossover frequency ratios for the six pilots. The total amount of data varies for each pilot, depending on the number of evaluations made for the HUD tracking tasks, and all relevant cases from Appendix B have been included on Figure 39. (Note that it requires at least three separate evaluations to produce a single point on these plots: first, the pitch case alone; then the roll case alone; and finally, the combined pitch/roll case. With repeat runs, the number of evaluations performed for all of the data in Figure 39 is quite large.)

All of the pilots show some evidence of division of attention, though the details of how their attention is divided between the two axes is idiosyncratic. Based on a review of Figure 39, the individual pilot behaviors may be summarized as follows:

- Pilot B: Tendency to back off in pitch (reduce the pitch crossover frequency) to attempt to maintain roll performance; in some cases, roll performance actually improved over the roll-alone runs.

- Pilot H: With only two exceptions (Cases 9H and 13H), a direct tradeoff between pitch and roll, i.e., both crossovers were reduced for the multi-axis cases. In general, for the more degraded roll cases (cases with B, C, and I in roll), pitch crossover was reduced in an effort to maintain roll performance (these cases are near the 1.0 line in roll); for the more degraded pitch cases (with 4 and 6 in pitch), the opposite is true.

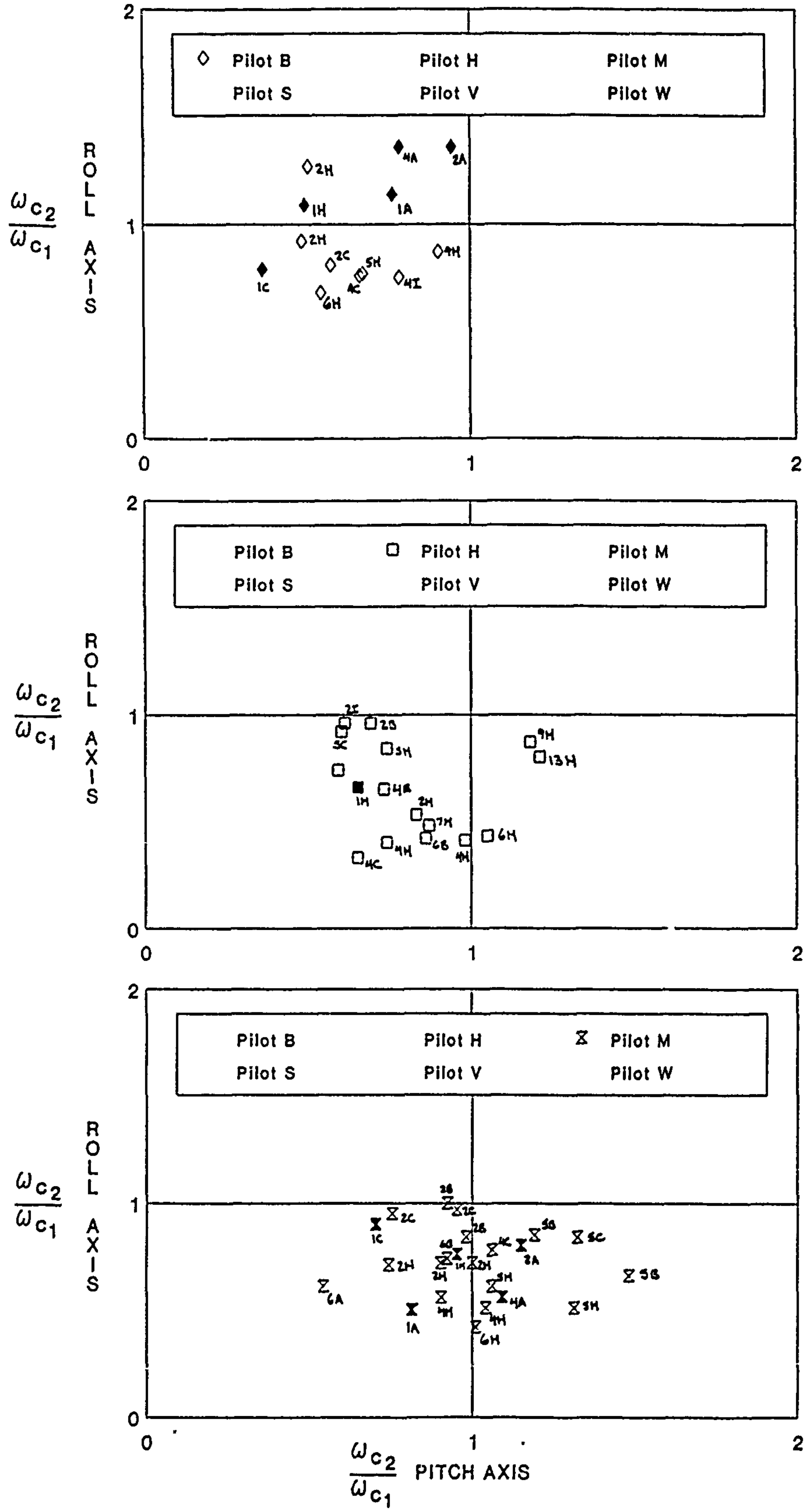


Figure 39. Crossover Frequency Ratios for HUD Tracking (Pitch/Roll -- see Figure 25) from Moving-Base Simulation. Solid Symbols Indicate Cases with k/s in One- or Both-Axes

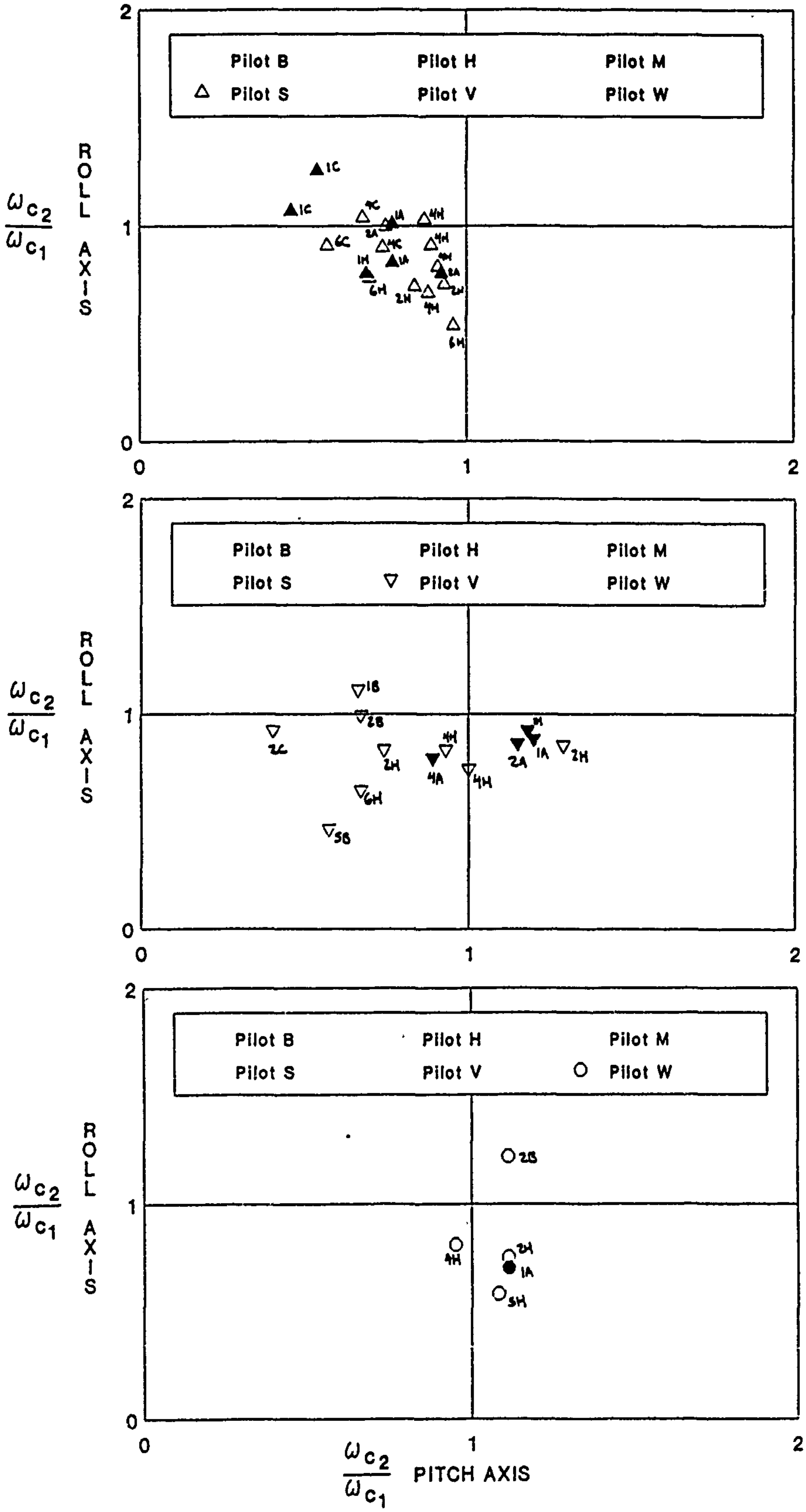


Figure 39. (Concluded)

- Pilot M: Tendency to reduce roll to maintain pitch performance.. All multi-axis cases have roll crossover frequencies lower than the single-axis cases, while pitch crossover frequency may go either up or down. Almost all degraded roll cases are near the top of the data, and almost all degraded pitch cases are to the right of the 1.0 line in pitch.

- Pilot S: Very similar to Pilot H, with a possible bias toward the roll axis (i.e., the data points are shifted slightly toward the 1.0 line in roll).

- Pilot V: Similar to Pilot M, but the degraded pitch cases all have reductions in both pitch and roll crossover frequency (with a single exception where there was no change in pitch, Case 4H).

- Pilot W: There are too few points (five) to make a determination of his behavior.

The data for Pilots H and M can be compared with their fixed-base data from the STI simulation (Figure 25). For Pilot H (Figure 25b), the trends for the moving-base simulation are much clearer, though the fixed-base data show some similarities. For Pilot M (Figure 25d), the attention to the roll axis is apparent in both plots, but while roll crossover frequencies sometimes increased in the multi-axis case fixed-base, this is not true for the moving-base data of Figure 39. It is possible that for both pilots, the strong motion cues resulted in near-optimal performance in all axes, while for the fixed-base simulation, it was not uncommon to actually perform better for the multi-axis task for some runs, thus increasing the overall data scatter in Figure 25 compared to Figure 39.

F. ADDITION OF AIRSPEED CONTROL SIDETASK

A low-frequency, low-amplitude sidetask was added to force the pilots into conditions of divided attention. For this task, a separate controller (throttle lever) was used to null airspeed errors displayed on a separate part of the HUD (see Appendix B). Most of these evaluations were performed by two pilots, Pilots M and V. Runs were always made for the speed-alone case to calibrate the pilots to the forcing function and display, with evaluations conducted for pitch/airspeed, roll/airspeed, and pitch/roll/airspeed control.

Since the airspeed control task was considered to be a sidetask, rather than a primary tracking operation, the effects of adding this task cannot be assessed by plotting crossover frequency ratios. Instead, the change in pitch or roll crossover frequency due to addition of airspeed tracking is plotted against the pitch or roll crossover frequency obtained for the no-airspeed task. In order to maximize the data base, two-axis (e.g., pitch/airspeed) and three-axis (pitch/roll/airspeed) results are included on the same plots.

Figure 40 shows the results for the addition of the airspeed task. In general, when the sidetask is added, crossovers in the primary axis are reduced, as the pilot must now divide his attention between the primary task and the sidetask. The lower the initial crossover frequency, the less this reduction due to the sidetask. The lone exception is for control of roll by Pilot V, where a more or less uniform reduction in roll crossover occurs when the sidetask is added.

Comparison of pilot ratings for HUD tracking with and without the throttle sidetask is shown in Figure 41. This figure includes all data for the airspeed sidetask, including ratings from Pilots B and S, who flew only a few cases. (The pilots were also asked to evaluate the airspeed-alone task, for which an average HQR of 2.0 was given.) There were indications of a learning effect with the sidetask: early runs with the airspeed task added were rated much higher than later runs, and the pilots especially noted the apparent inconsistencies between the pitch and airspeed signals, since the two signals were not physically related. There was also some initial adjustment to the Head-Up Display format, since the airspeed error cursor was to the left of the attitude indicator. Errors in both axes were significantly increased if the pilots tried to glance from one display to the other. Most pilots gradually adopted a strategy of monitoring the movement of the left side of the attitude error bar, so that the airspeed error cursor was in their primary field of view. Even with this strategy, all pilots commented on the high workload involved in simply attempting to monitor both signals simultaneously. In order to minimize any learning effects for both the airspeed and primary tracking tasks, as well as day-to-day variations in pilot opinion, the HQRs in

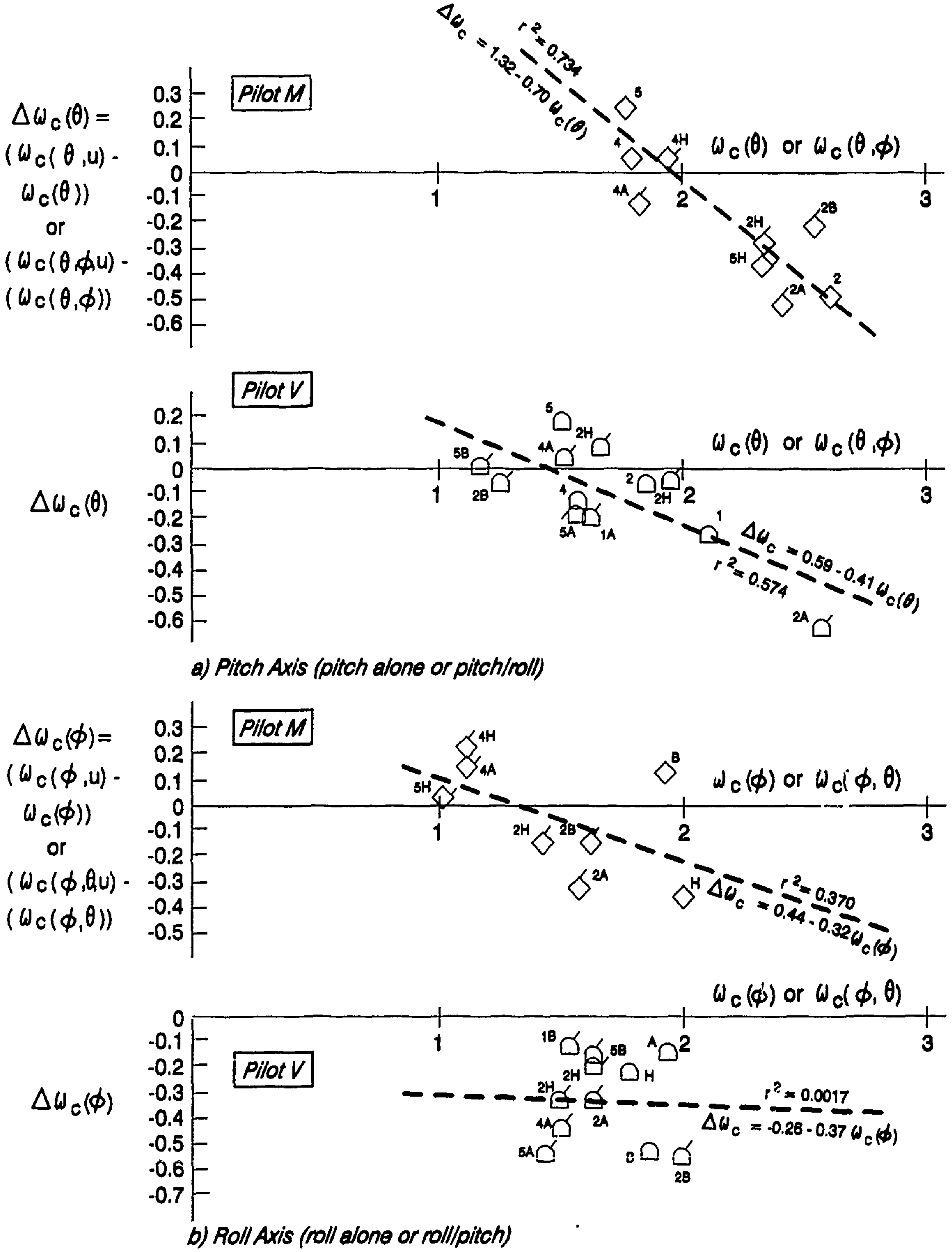


Figure 40. Effect of Adding Airspeed Control Task to Pitch and Roll Crossover Frequency (Flagged Symbols Denote Pitch/Roll Cases)

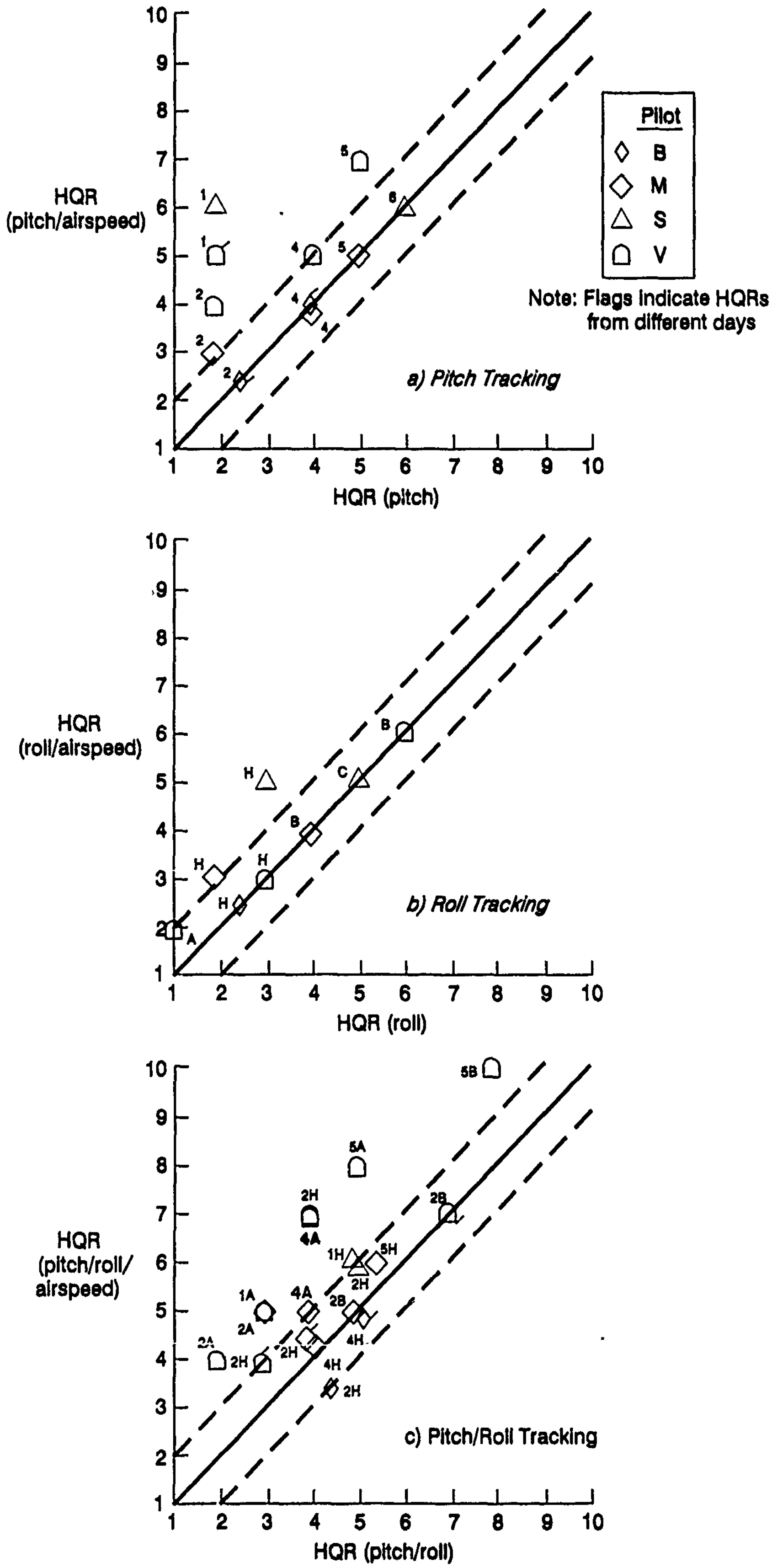


Figure 41. Comparison of HQRs for HUD Tracking With and Without Airspeed Sidetask (All Pilots, All Runs)

Figure 41 are cross-plotted for runs made in the same day, with exceptions noted by a flagged symbol.

Several key differences between axes show up in the HQR plots of Figure 41. For pitch, Figure 41a, the general tendency is for little change in HQR with the added task. Several notable exceptions occur, however. This is contrasted with roll, Figure 41b, where the ratings are almost always identical with and without the airspeed sidetask. The relatively strong agreement in roll as compared to pitch may reflect the problem noted above of the apparent inconsistencies between the pitch and airspeed commands. An additional factor may have been the large relative error signal movements between airspeed and pitch (i.e., both travelled vertically on the HUD and were, at times, widely separated) compared to airspeed and roll (since for roll-alone evaluations the roll error signal remained centered vertically and showed only bank changes). There was also a possibility of greater confusion over what inputs were required when both control motions were in-plane as opposed to out-of-plane.

Pitch/roll tracking with and without the airspeed sidetask shows a clear degradation in pilot rating, Figure 41c. Of the 18 data points in Figure 41c, only four show the same (or improved) HQRs for the three-axis task. Of these four, two points are based on HQRs taken on different days, and there may be evidence of a learning effect. All other cases were rated 1/2 to 3 rating points worse for the three-axis task. To the extent that pilot ratings reflect pilot workload, this suggests an incrementally higher level of workload going from two axes to three than going from one axis (pitch or roll) to two (pitch/airspeed or roll/airspeed). It is significant that only one Level 1 HQR was assigned for the three-axis task, even when the dynamics for the primary axes were otherwise good (e.g., Case 2A or 2H).

G. ADDITION OF NON-CONTROL SIDETASK

The theory of divided attention, as defined in Volume II of this report, states that division of attention will occur as a result of requirements to respond to both control (i.e., additional axes) and non-control (i.e., managerial) tasks. Plans to verify and quantify the non-control aspects of this theory were included in the moving-base

simulation matrix by devising a head-down sidetask using a flat panel display in the simulator's cockpit. A finger-actuated transducer located on the throttle lever drove a cursor on the flat panel, and whenever the sidetask was activated a pattern of numbered boxes would appear on the panel. A flashing message "TASK" simultaneously appeared on the HUD, and the pilot's job was to move the cursor to each box in numerical sequence while still performing the primary tracking task. Time required to complete the task was recorded.

Early in the simulation, attempts to implement this sidetask were met with varying success. For most pilots, the lack of familiarity with the finger-actuated control was in itself a drawback, as it was estimated that several hours of training might be required by each pilot before formal evaluations could be conducted.

A more fundamental problem precluded the addition of this, or any alternate, sidetask, however: the demands on the pilot to keep his attention fixed on the HUD were so great that even a momentary glance away could lead to a loss of control. The primary tracking task itself was simply too demanding to allow for any non-control operations.

This observation is, in itself, significant, since, for the best configurations single-axis, most pilots considered the tracking task a lot of work but not unreasonable (as reflected in their HQRs), and not unlike aggressive air combat.

The most obvious remedy to the high-workload environment would have been to reduce the primary-axis forcing function bandwidth and/or amplitude. High values of both were required to elicit the desired closed-loop compensatory tracking behavior, and short of an extensive sweep of these parameters, no compromise could be determined. Since the multi-axis operations (either pitch/roll or with airspeed added) produced behavior consistent with the theory of divided attention, it was felt that further work on development of a non-control sidetask was not justified.

H. RESULTS FOR AGGRESSIVE LOW-LEVEL MANEUVERING TASKS

A series of visual tasks were devised using the out-the-window camera model/terrain board system of the LAMARS. These tasks were intentionally designed to emphasize pitch, roll, or the combination, as a means of comparing the HUD tracking results with more "real-world" tasks. The details of these maneuvers are given in Appendix B; they consisted of a wings-level dolphin (climbs to a specified altitude at a specified pitch attitude, and dives to an altitude with the flight path vector pointed at a ground target); a constant-altitude slalom (using ground reference points for the turns); and a combination maneuver involving altitude and heading changes. All tasks ended with a dive to a runway and constant-altitude flight over the runway. The performance criteria for pilot ratings are given in Appendix B.

Pilots H, S, and W were the primary evaluators for these tasks. As with the HUD tracking evaluations, at least two runs were made before HQRs were assigned. The pilots were allowed to adjust the control/response sensitivities to their liking before making a formal run; Pilot W always chose very high sensitivity in roll, resulting in pilot-induced oscillations for almost all configurations and very poor HQRs. For most runs, the stick sensitivities for Pilot W were fixed at a value close to those chosen by the other two pilots, and his HQRs then fell more in line with the others.

As devised, the dolphin (pitch) task was not significantly different from the HUD tracking task, in that only relatively small (±5 deg) attitude changes were required. The slalom and combined tasks were significantly different, however, as bank angles as high as 60 deg were reached in the turns, compared to 10-15 deg during the roll HUD tracking. Any differences in HQRs due to task effects should, therefore, show up in the slalom and combined maneuvers.

The effects of inter-pilot variations in ratings for the visual tasks are apparent in Figure 42. The most obvious difference is for Pilot W, who rated the slalom and combined tasks much higher (in number) overall than either Pilot H or Pilot S. As mentioned above, Pilot W always re-

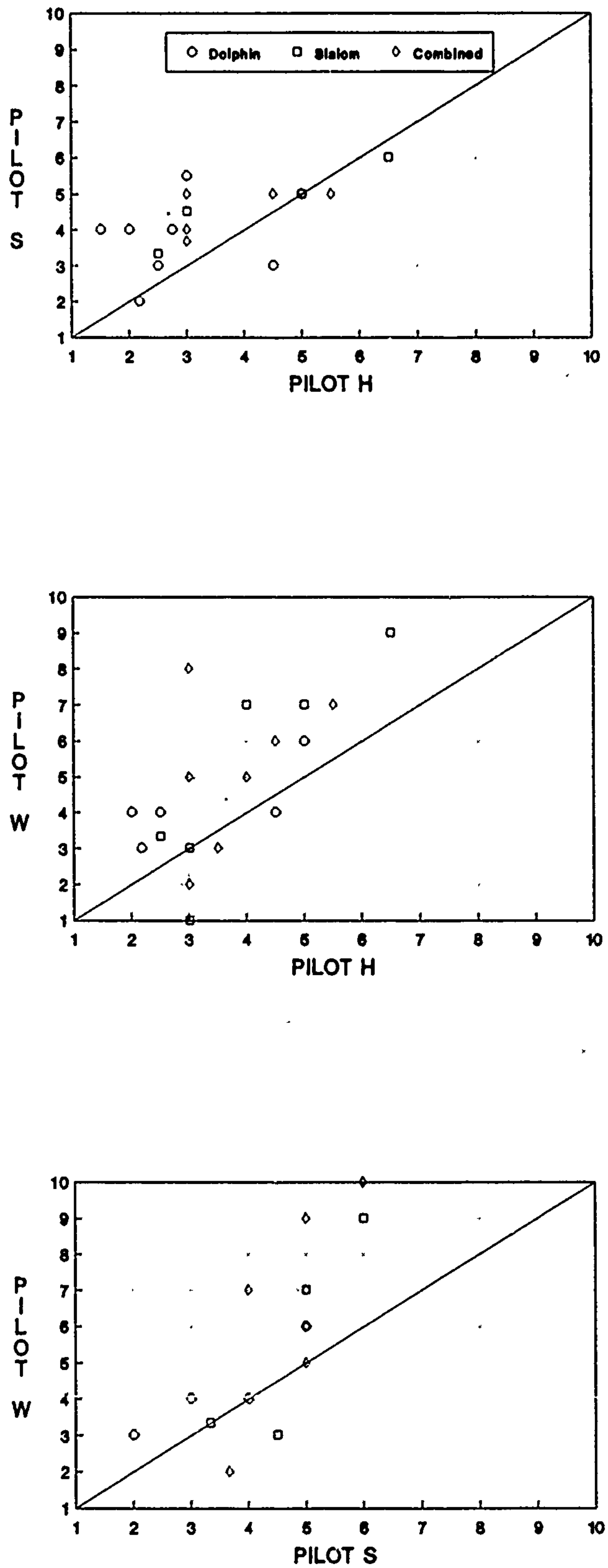


Figure 42. Comparison of HQRs for Visual Tasks (All Ratings, All Tasks)

quested very light stick forces in roll and flew every case very aggressively, resulting in PIOs, whereas the other pilots tended to request heavier forces for the degraded cases. An additional, smaller difference is noted in Figure 42 for Pilot H, who did not seem to notice the degraded pitch dynamics for some configurations in the dolphin and combined tasks, and hence generally rated these better than Pilot S or Pilot W. The inter-pilot scatter is larger here, as one would naturally expect given the combination of a less constrained task, limited field-of-view, and degraded outside visual cues from the camera/projection system.

Figure 43 summarizes the HQR differences found between the HUD tracking and visual tasks. Each point represents the same transfer-function model flown for both tasks by the same pilot. The ratings are averages for all runs by that pilot. A limited number of evaluations by Pilot B are included.

The data for pitch tracking compared to the visual dolphin maneuver, Figure 43a, show a tendency toward better ratings in the visual task. Based on pilot comments, the most significant difference is a lack of awareness of the high time delays for the dolphin maneuver. This task required more-or-less steady (in the short term) pitch attitude changes, and not the tight, continuous tracking that was involved in the HUD task. A secondary effect was a slightly greater tolerance for low short-period damping in the dolphin, again because there was no tendency to tightly control pitch and therefore excite this mode.

The roll-axis ratings, Figure 43b, indicate generally worse HQRs for the slalom compared to the HUD roll tracking task. This is due primarily to the requirement to make much larger bank angle changes, resulting in occasional overshoots and PIO tendencies.

For the combined-axis task, Figure 43c, the different individual effects mentioned above cancel out, and the result is a very strong agreement in overall HQR with that assigned for the pitch/roll HUD tracking.

In general, while there are some consistent differences due to task, the data of Figure 43 indicate that there were no overwhelming differences, i.e., that the HUD tracking task was effective at eliciting pilot ratings very similar to those for a more realistic set of maneuvers.

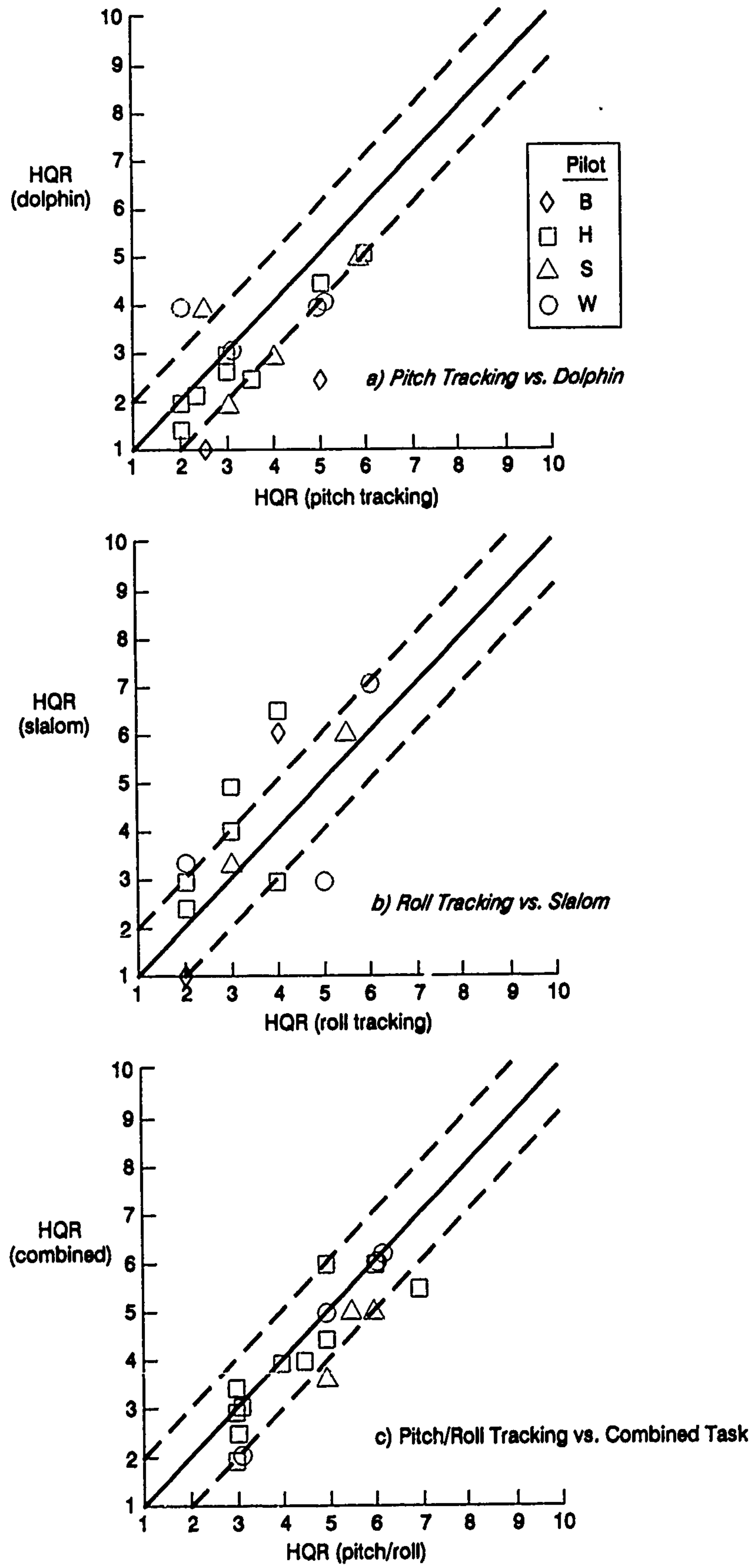


Figure 43. HQR Comparisons for HUD Tracking and Visual Tasks

I. MULTI-AXIS PILOT RATING SUMMARIES

Figures 44 and 45 show the dual-axis HQRs compared with the respective single-axis ratings in pitch and roll for the HUD tracking tasks. These data suggest a larger Level 2 region than was found for the fixed-base simulation results (Figure 29), but it is impossible to conclusively show this since there is a lack of data with roll HQRs in the 4-6 range. Figure 44 confirms the expectations of the Product Rule, i.e., the HQRs for the multi-axis HUD tracking task are almost always higher (worse) than the HQRs for either axis alone.

The smaller data base for the low-level visual tasks, Figure 45, suggests a similar set of boundaries. It also appears that the pilots were less sensitive to degradations in the pitch axis when roll flying qualities degraded; this is reflected by the flat Level 2 limit sketched in Figure 45 for a constant roll HQR of 6.5, and may be a reflection of the dominance of roll maneuvering over pitch for the combined-axis terrain following task.

The data of Figures 44 and 45 are reexamined in the next section for specification of revised Product Rule formulations.

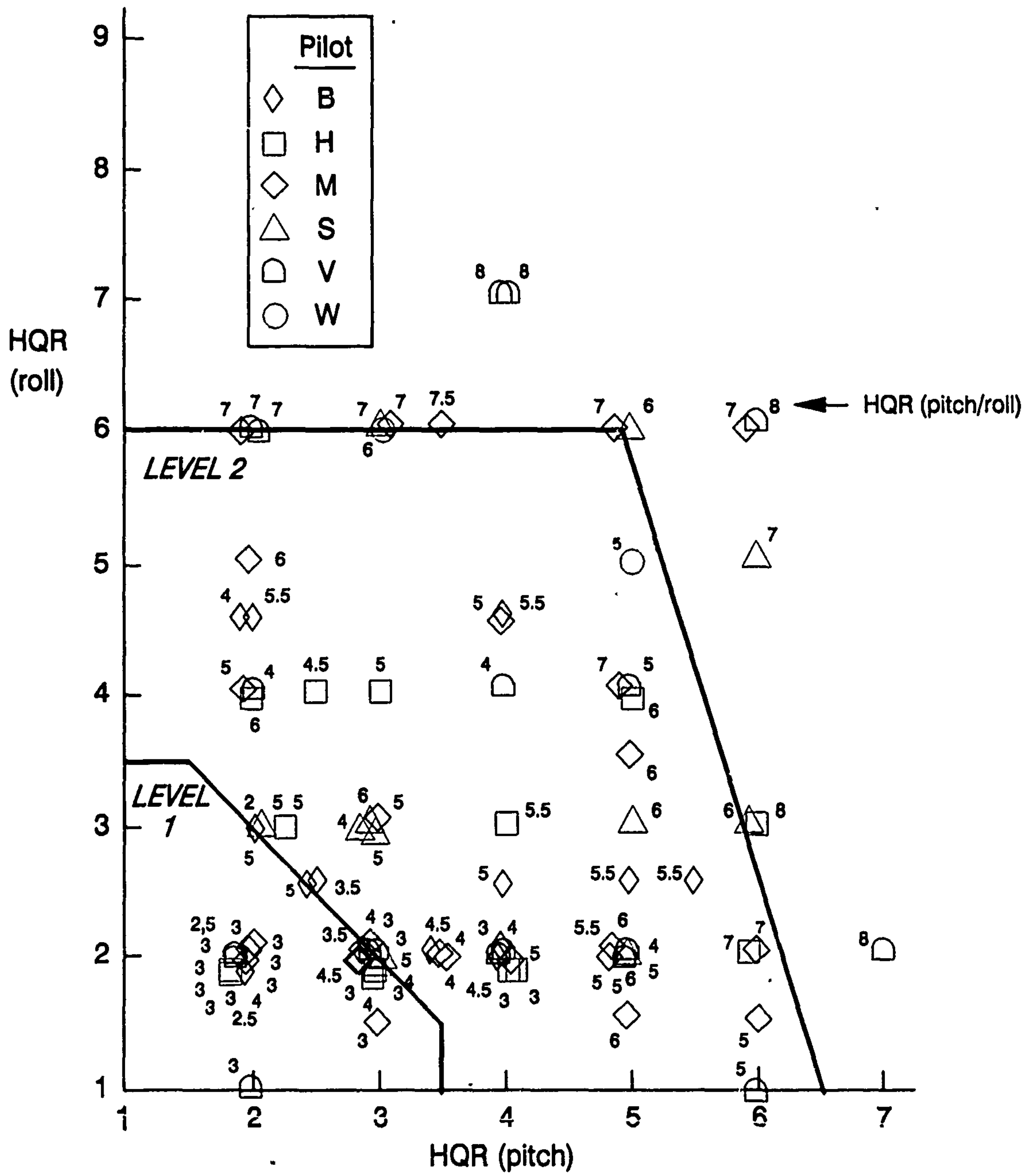


Figure 44. Multi-Axis Handling Qualities Ratings for Pitch/Roll HUD Tracking Tasks

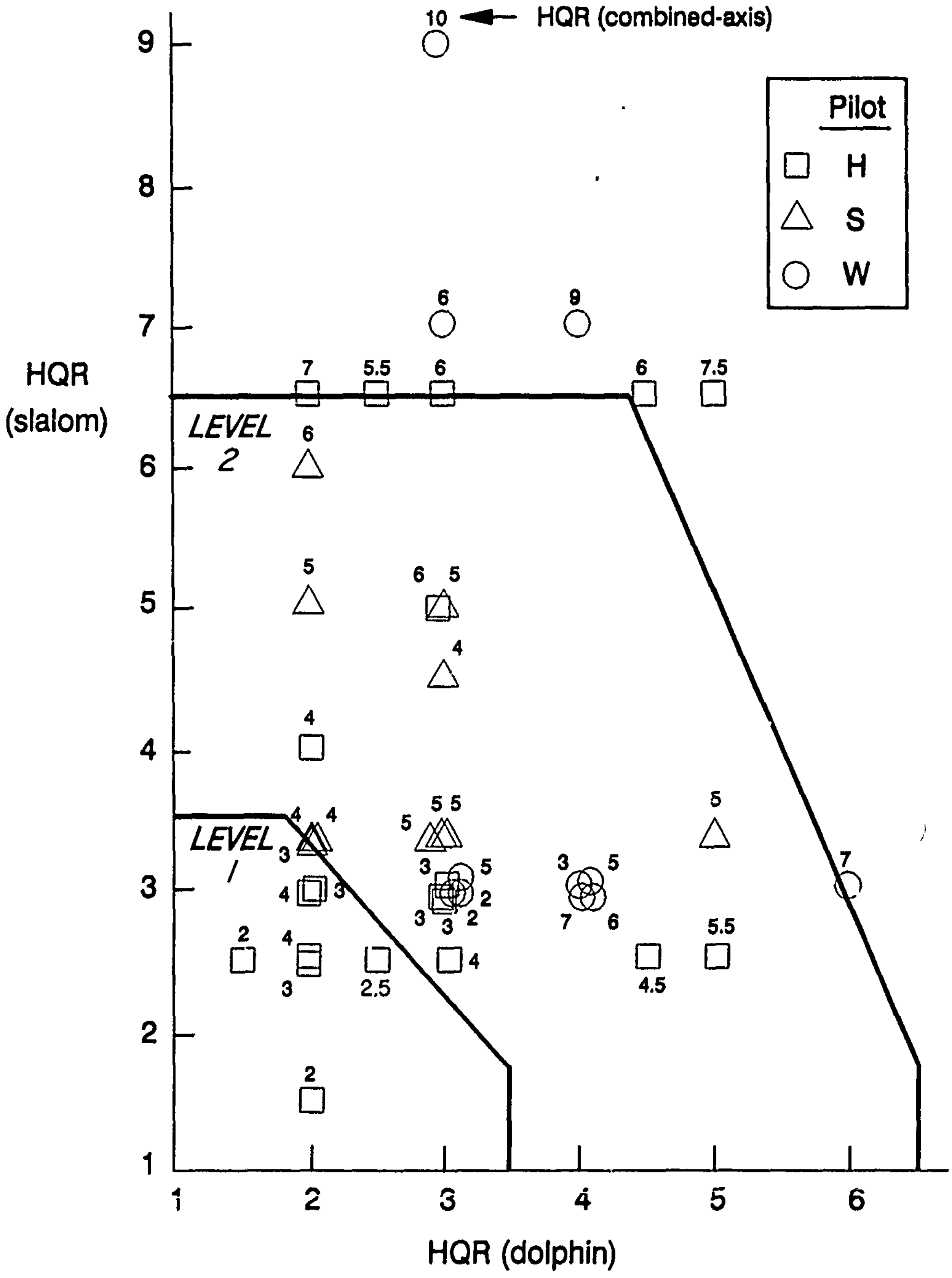


Figure 45. Multi-Axis Handling Qualities Ratings from Low-Level Tasks

SECTION VII

RECOMMENDATIONS FOR ESTIMATING MULTI-AXIS FLYING QUALITIES

A. ALTERNATIVE APPROACHES

There are currently three alternative approaches for estimating flying qualities Levels for multi-axis operations. These are:

- Analytical (Structural) -- Construction of pilot models based on analytical techniques, and estimation of the pilot ratings from these models;
- Analytical (Optimal) -- Application of the optimal control model, and estimation of pilot ratings from correlations of cost functionals;
- Experimental -- Estimation of single-axis ratings from applicable criteria (e.g., bandwidth) and computation of the associated multi-axis ratings through the Product Rule.

The first and second approaches are documented in Volumes II and III. The second and third approaches have been applied in this volume for the fixed- and moving-base simulation data of Appendices A and B. This section summarizes the results of the OCM application to for the moving-base simulation data from the last section, and derives refined regression equations for estimating HQRs based on bandwidth frequency and phase delay.

B. RESULTS OF OCM ESTIMATES

The Optimal Control Model (Volumes II and III) generates both a model of the pilot/vehicle system and a cost function, J. The former can be used to determine pilot behavior, while the latter can be applied for estimates of HQRs (Figure 9). Figure 46 shows the cost function/rating correlations for the moving-base simulation data (single- and dual-axis HUD tracking). With the exceptions of the two pitch cases with low damping ratio (Cases 5 and 6), correlation is excellent. (Because of the problems of the OCM in properly estimating pilot models for the low-damped cases, the dual-axis combinations with Cases 5 and 6 are not included in Figure 46. If they were, correlation would be much poorer, but the reasons for this poor correlation are known.)

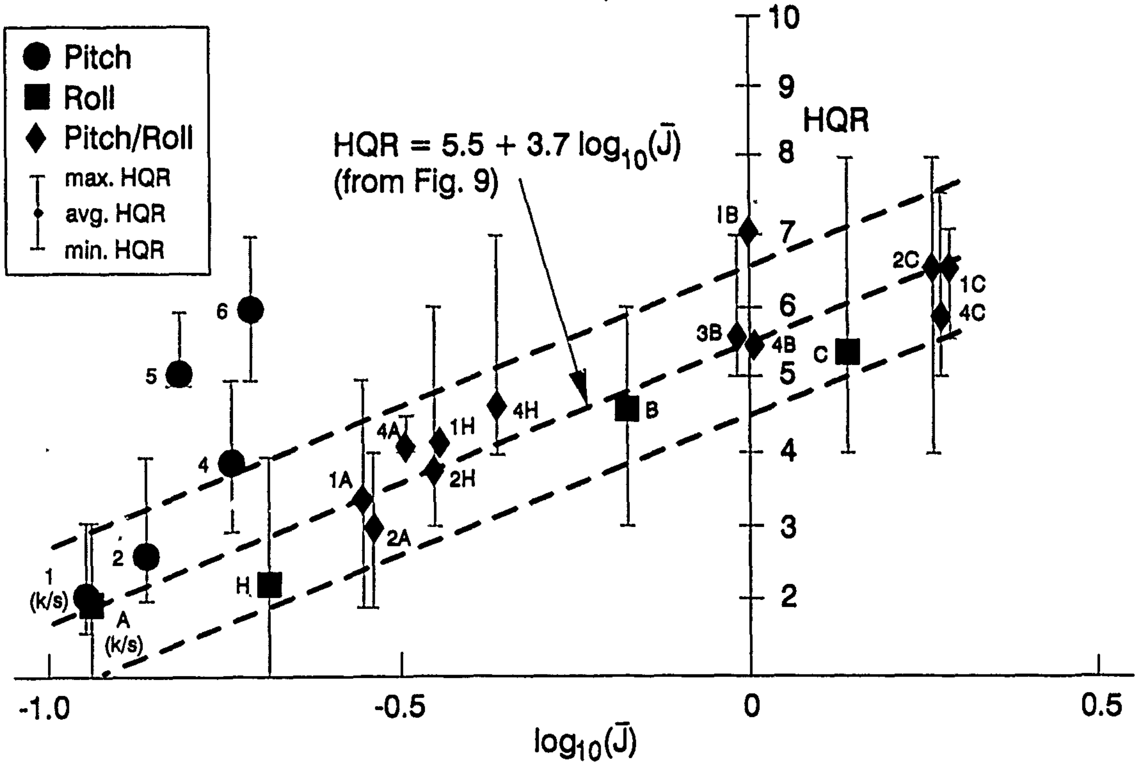


Figure 46. Cost Function/Rating Correlation for Moving-Base Simulation Data (Cases 5A, 5B, 5C, 5H, 6A, 6B, 6C, 6H Not Shown) $[\bar{J} = J/(\sigma_c^2\ \omega_w^2)]$

The OCM approach to estimating multi-axis handling qualities has several obvious advantages. Among these is the capability of extending the approach to three axes (Reference 15), and potentially more. In addition, a natural outcome of the STI formulation of the OCM is a model of the pilot-vehicle transfer function, from which models of expected pilot behavior may be extracted. Disadvantages include the requirement to have <u>a priori</u> linear models of the effective aircraft and the ability to approximate the pilot's task in terms of pure tracking with known bandwidth and amplitude. The OCM has also been shown in this study to be inapplicable in its current form to configurations where it is expected that the pilot will be required to generate lag near the region of pilot-vehicle crossover.

C. DEVELOPMENT OF REFINED BANDWIDTH/PRODUCT RULE EQUATIONS

1. Revised Bandwidth Regressions for Single-Axis HQR Estimates

In Section V the single-axis pilot ratings from the fixed-base simulation were used to define new boundaries for the bandwidth criteria. A similar step has been taken in Figure 47 for the HUD tracking results (there are too few ratings for the visual tasks to apply these data as well). The refined boundaries from the moving-base simulation results should be more generally applicable for flight operations. Figure 47 shows both "eyeball" Level 1 limits (solid lines) and limits computed from linear regression fits to the actual HQRs (dashed lines). Data for a wide range of bandwidth frequencies are available for pitch, but the roll cases are (with the exception of k/s, Case A) clustered below about 2.3 rad/sec. Since the ratings for Case A (which are only slightly better on average than those for Case H, for a relatively much higher bandwidth) would tend to skew a linear-regression match, these ratings were excluded from the fitting process.

For pitch, the linear regression fit to the data gives:

$$\hat{R}_\theta = 3.8 - 0.27\, \omega_{BW_\theta} + 5.7\, \tau_{p_\theta}$$

The number of points, n, is 72, and the correlation coefficient $r^2 = 0.643$, indicating a greater than 99% level of confidence that the parameters are correlated. For roll, the fit is:

$$\hat{R}_\phi = 4.54 - 1.31\, \omega_{BW_\phi} + 7.2\, \tau_{p_\phi}$$

with $n = 45$ and $r^2 = 0.633$, giving a level of confidence of greater than 99%. This linear equation will estimate HQRs of less than one for high-bandwidth aircraft (such as the k/s configuration); in such instances, it has been customary to assume an estimated HQR of 1.

As a check of the effectiveness of the linear regression equations, the single-axis HQRs were estimated for all pitch and roll cases evaluated on the LAMARS (Appendix B). Figure 48 is a crossplot of all pilot ratings from the simulation against computed HQRs from the regressions. Both equations are very successful as indicated by various measures noted on

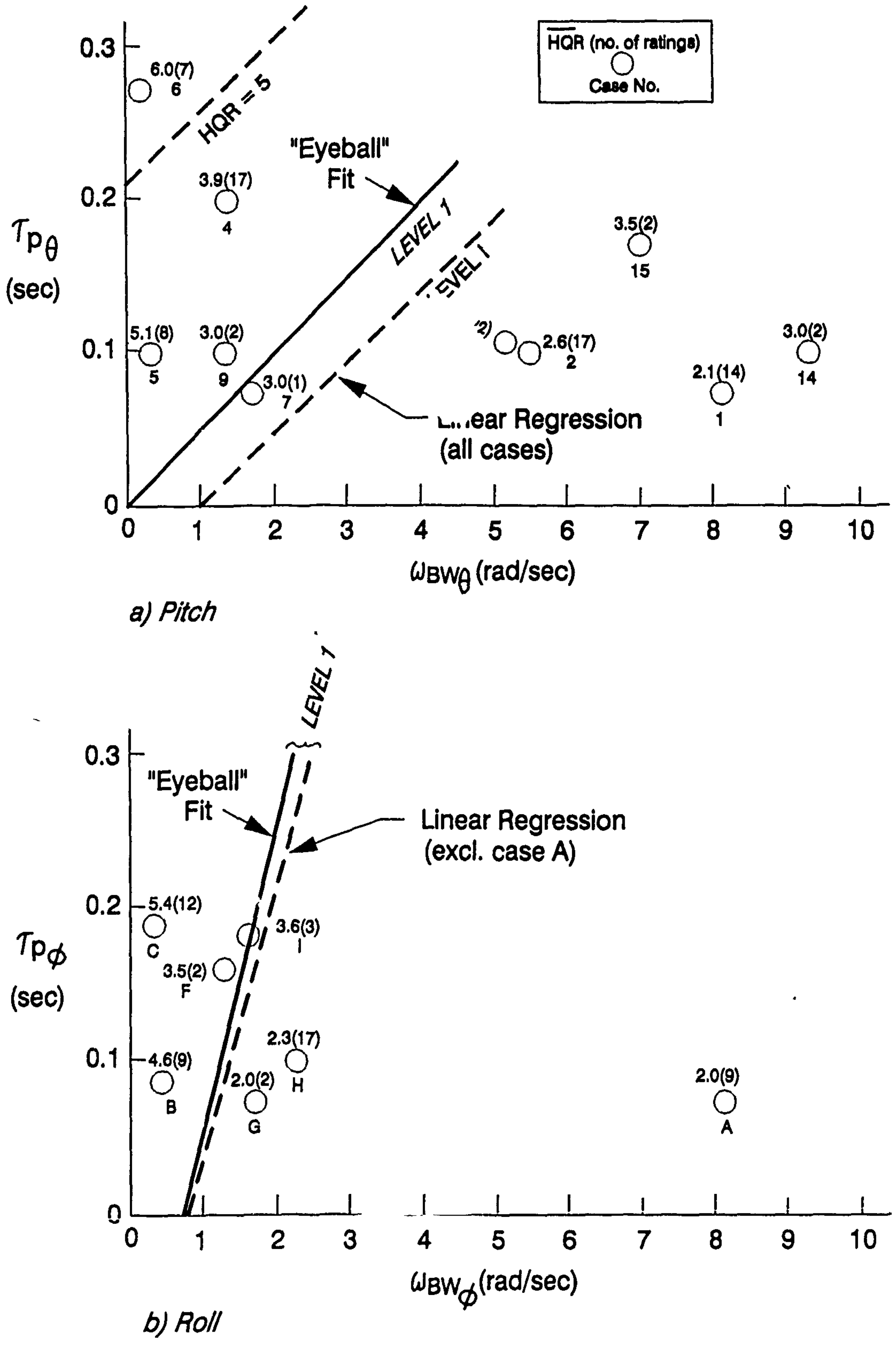


Figure 47. Revised Bandwidth Boundaries for Moving-Base Simulation Data (Single-Axis)

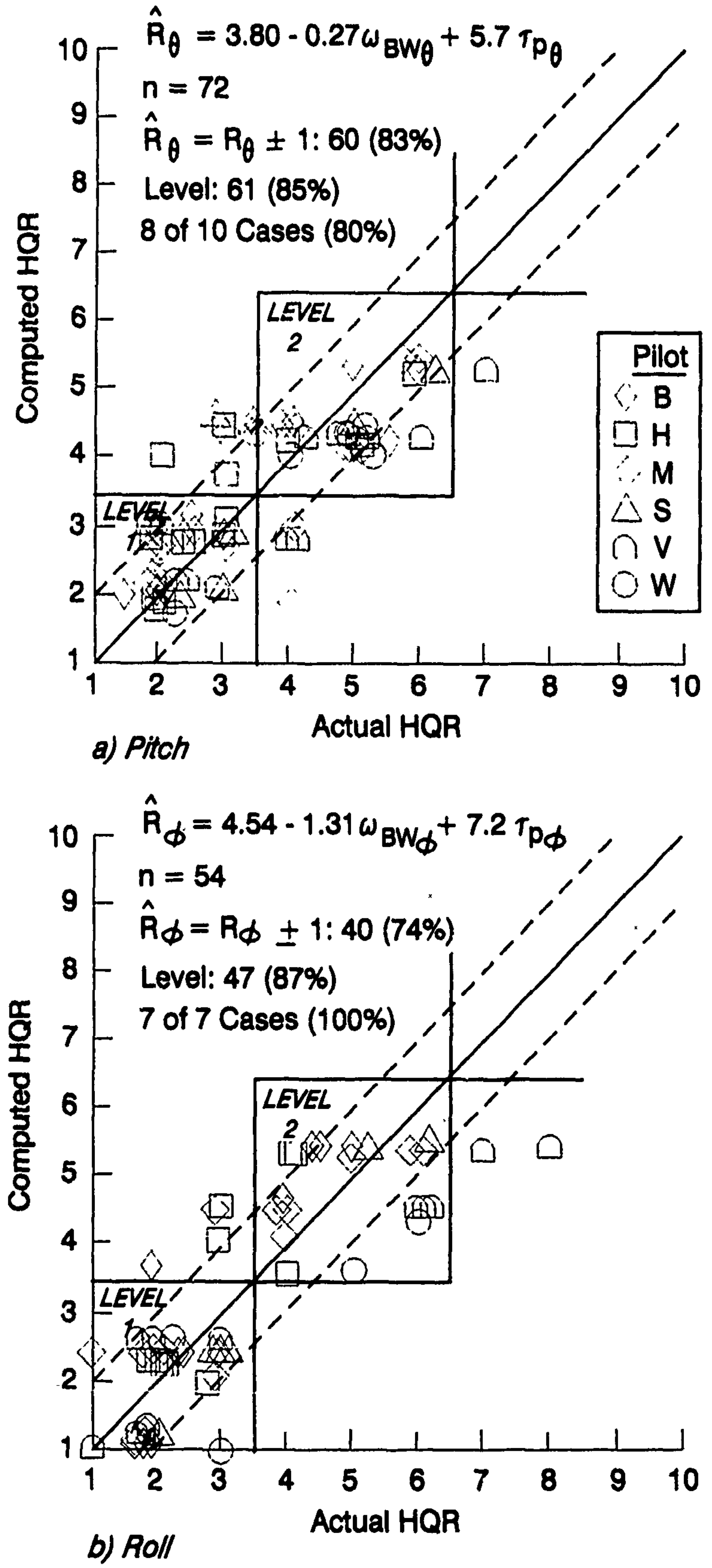


Figure 48. Correlations of Computed HQRs from Single-Axis Linear Regressions with Actual HQRs from Moving-Base Simulation (HUD Tracking)

Figure 48. For pitch, Figure 48a, the estimated ratings from the regression were within ±1 rating point for 60 out of 72 ratings, for a success rate of 83%; 61 of the ratings (85%) were correctly estimated within the same Level; and overall, 8 of the 10 cases (80%) were correctly predicted to be within the Level indicated by the average HQRs. (The two exceptions, Cases 7 and 9, can be seen on Figure 47a to be only slightly beyond the Level 1 limit. These cases were evaluated a total of three times by two pilots; Pilot H assigned HQRs of 3 to Case 7 and 2 to Case 9, while Pilot W gave Case 9 a 4.)

Correlation in roll, Figure 48b, is not quite as high as for pitch in terms of the individual ratings, but is better in terms of the overall Levels. The roll regression-estimated ratings were within one rating point of actual HQRs for 40 out of 54 cases, for a success rate of 74%; 47 ratings were estimated to be within the correct Level (87%) and the Levels for all 7 roll cases were correctly predicted, for a 100% success rate.

2. Refined Product Rule for Combining Single-Axis HQRs

The single- and dual-axis (pitch and roll) HUD tracking pilot ratings were applied to the elliptical equation form described in Section V, resulting in a revised Product Rule for combining single-axis ratings. The resulting equation, and the Level 1 and 2 limits specified by this equation, are shown on Figure 49.

3. Combined Regression/Product Rule for Dual-Axis HQR Estimates

The computed single-axis HQRs (Figure 48) were applied to the Product Rule of Figure 49 to make overall estimates of the dual-axis HQRs for the HUD tracking task. The correlations for these purely analytical ratings with the actual numbers are plotted in Figure 50. There is a noticeable shift in the plot, indicating a tendency for the ratings to be underestimated (i.e., actual ratings worse than computed ratings). On the other hand, of the 25 dual-axis cases evaluated, the flying qualities Levels are correctly computed for 17, with the 8 exceptions listed on Figure 50. Four of the exceptions were rated only once, and one was rated twice. Case 2H was evaluated a total of 13 times, receiving HQRs between

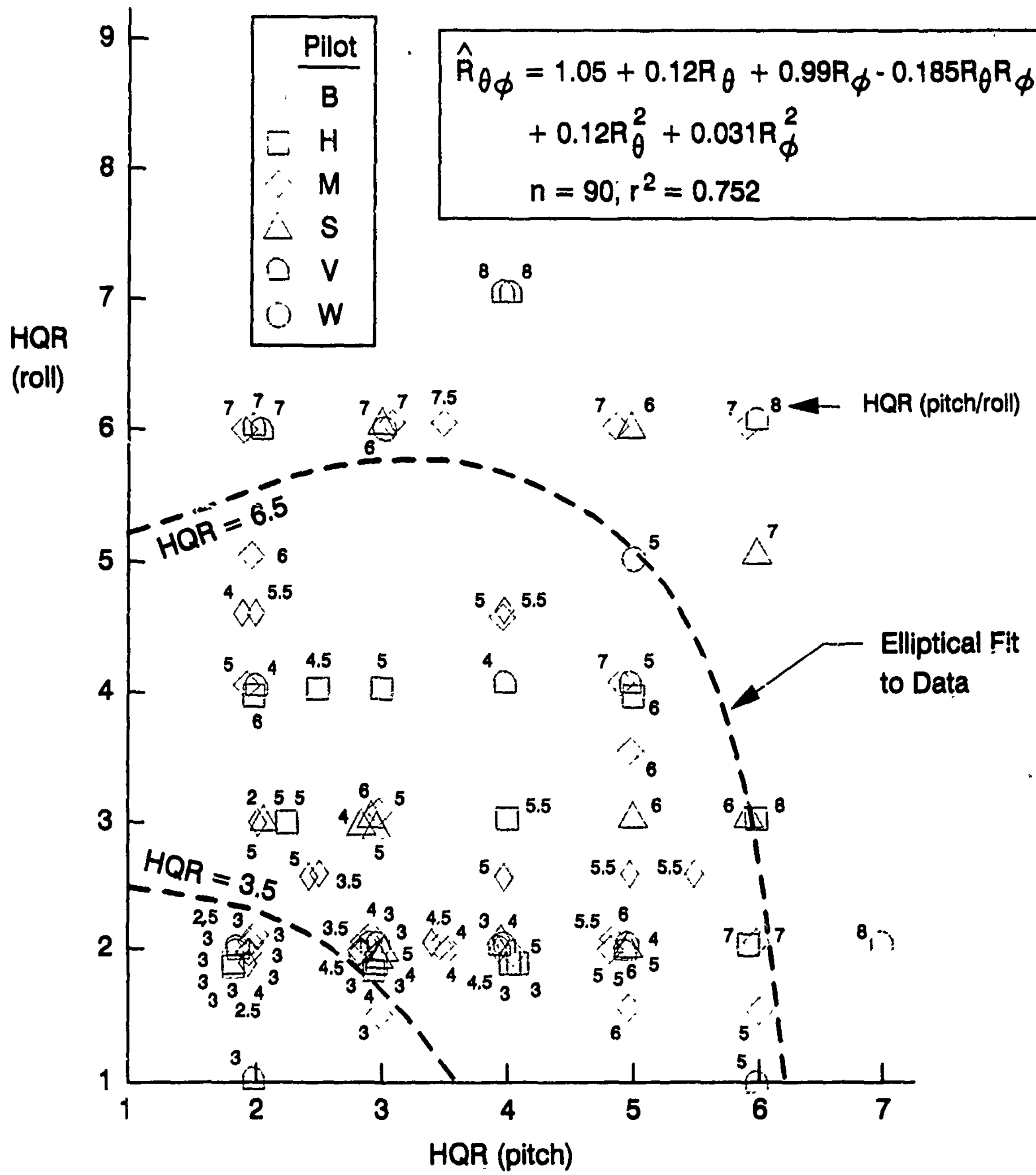
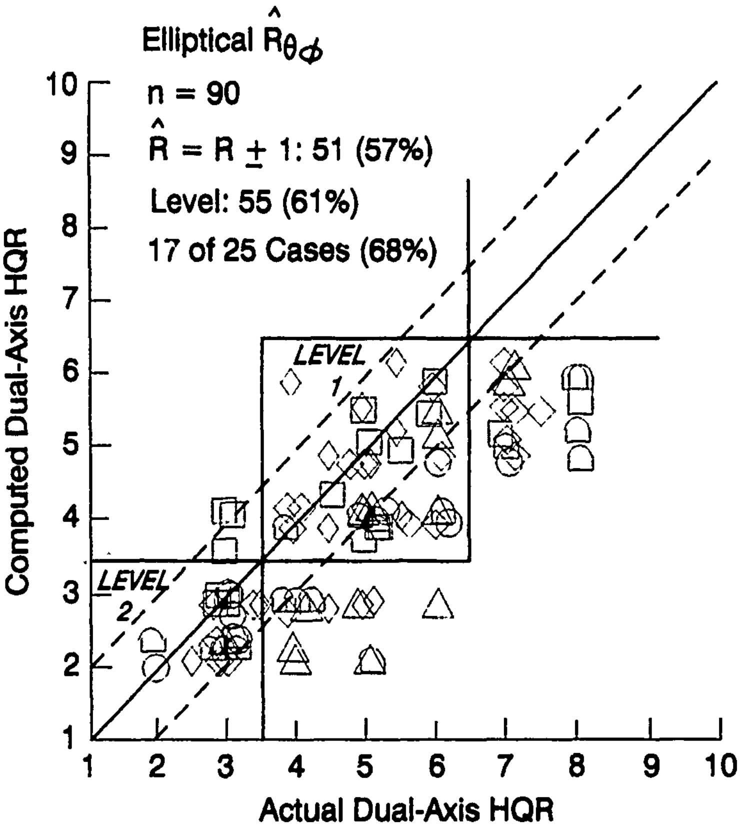


Figure 49. Product Rule Regressions for Dual-Axis (Pitch and Roll) HQRs from Moving-Base Simulation (HUD Tracking)



Levels for 8 Multi-Axis Cases are not Predicted Correctly:

CASE	EST. HQR	ACTUAL HQRS (PILOT)	AVG. HQR
1B	5.0	7(V)	7.0
1H	2.9	5(B),3(H),5(S),4(V)	4.2
2H	2.9	3.5,5,4.5,(B); 3(H); 3.5,3,4(M); 6,4(S); 4,4,3(V); 3(W)	3.8
5B	4.9	6,7(M); 8(V)	7.0
6A	5.1	7(M)	7.0
6B	5.6	8(H); 7(M)	7.5
6C	5.9	7(S)	7.0
9H	3.7	3(H)	3.0

Figure 50. Correlations of Computed HQRs with Actual Dual-Axis (Pitch and Roll) HQRs from Moving-Base Simulation (HUD Tracking)

3 and 6, with 6 ratings in the Level 1 region, resulting in an average HQR of 3.8.

D. A METHOD FOR ESTIMATING DUAL-AXIS PILOT RATINGS

A recommended method for estimating dual-axis HQRs, given the bandwidth parameters (frequency and phase delay) for the pitch and roll axes, is as follows:

1. Compute the estimated single-axis HQR for pitch:

$$\hat{R}_\theta = 3.8 - 0.27\,\omega_{BW_\theta} + 5.7\,\tau_{p_\theta}$$

subject to the limits $1 \le \hat{R}_\theta \le 10$;

2. Compute the estimated single-axis HQR for roll:

$$\hat{R}_\phi = 4.54 - 1.31\,\omega_{BW_\phi} + 7.2\,\tau_{p_\phi}$$

subject to the limits $1 \le \hat{R}_\phi \le 10$;

3. Compute the estimated multi-axis HQR for pitch and roll:

$$\hat{R}_{\theta\phi} = 1.05 + 0.12\hat{R}_\theta + 0.99\hat{R}_\phi - 0.185\hat{R}_\theta\hat{R}_\phi + 0.12\hat{R}_\theta{}^2 + 0.031\hat{R}_\phi{}^2$$

subject to the limits $1 \le \hat{R}_{\theta\phi} \le 10$.

The most obvious advantage of this method is its applicability even if an accurate transfer-function model of the aircraft has not been obtained: the only input parameters are measured from frequency responses of pitch and roll attitude. It is very limited in its range of application, however, since the equations were derived specifically for pitch and roll attitude control. Extension to other dual-axis situations (such as roll and yaw), or to more than two axes, is not possible without further study and expansion of the equations. More general nonlinear HQR regression equations may also be necessary to cover situations of high bandwidth and high phase delay.

E. RECOMMENDATIONS FOR FUTURE STUDY

More work is clearly required in the field of minimum flying qualities. The work performed under the current contract has vastly expanded our knowledge of this area, and the data base generated (Appendices A and B) holds much more information than it has been possible to exploit in this analysis. Future investigations should expand the matrix of aircraft dynamics evaluated, including additional airspeed variations and extension to a fourth axis (yaw control).

If a more extensive simulation were to be conducted, a systematic variation in forcing function dynamics (for one set of aircraft dynamics) would provide insight into the importance of input bandwidth and amplitude on the results reported here. A full range of evaluations for single-axis tracking, with the other axes free (but with no forcing functions), would determine the effects of freezing the off-axes as was done in this study.

SECTION VIII

CONCLUSIONS

The experimental and analytical work performed under the present study has significantly increased the knowledge base for minimum flying qualities, and has provided some first steps toward estimating the expected handling qualities for aircraft in conditions of multiply-degraded dynamics. Following is a summary of the most significant observations and conclusions revealed in the course of this study.

<u>For the simulations and their protocol:</u>

- The available data base for minimum flying qualities has been expanded. Prior to this study the data base was limited to one fixed-base experiment (Reference 3), from which only qualitative pilot ratings could be obtained. Under the present effort a large amount of both fixed- and moving-base experimental data has been produced, including qualitative pilot ratings as well as quantitative measures of pilot performance and pilot behavior in conditions of multi-axis control with degraded aircraft dynamics.

- A wide spectrum of subject pilots was used, resulting in a large pilot population for analysis of inter-pilot variations. Evidence of rating bias between pilots is a normal occurrence when a large sample is used; in the case of this study, however, the measured performance and behavioral data provided a means for investigating the sources of the rating bias.

- The primary task for the experiments, involving compensatory tracking of displayed errors in one, two or three axes, produced valid and repeatable data. The assumption used in setting the simulation scenarios was that the pilots would control the aircraft in a manner consistent with the crossover model, and this was found to be the case. Compensatory tracking was used as the primary evaluation task because it parallels "flying qualities while tracking" flight testing, permits simple measurement of pilot dynamic behavior, and allows for the application of classical and algorithmic pilot model theories and associated analytical techniques for data assessment and interpretation. As a consequence of the simple crossover model it was possible to limit the controlled-element variations to dynamics near the expected crossover frequency, since these dynamics are most important to the pilot.

- The best controlled element in all simulations, for both pitch and roll, was k/s near crossover. This is as expected from the crossover model, and is a further verification of the analysis techniques.

<u>For extension from single-axis to multi-axis tracking operations:</u>

- Adding axes to control, or multiple degradations in one axis (e.g., increasing time delay and decreasing damping ratio), results in degradations in pilot ratings. The effects of multiple-axis operations on pilot ratings have been quantified.

- Effects on pilot behavior and subjective pilot ratings of adding axes to control are generally as expected from the theory of divided attention (Volume II): the pilots will modify their priorities as needed to control the added axis, and performance in every axis is (generally) degraded compared to the respective single-axis case.

- The specific prioritizing for reallocation of attention between axes is idiosyncratic: in going from single-axis (pitch or roll) to dual-axis (combined pitch/roll) tracking, some pilots reduced crossover frequencies in pitch to concentrate on roll, some reduced roll crossover to concentrate on pitch, and others reduced both more or less evenly. All pilots were, however, internally consistent in their behavior.

- Addition of a third axis to control produces further degradations in pilot ratings and performance. The low-frequency airspeed control task used in the moving-base simulations caused only slight changes in HQR and performance when added to single-axis pitch or roll tracking, but significantly worse ratings (between 0 and 3 rating points) were obtained when this task was added to the dual-axis pitch/roll tracking task.

<u>For divided-attention operations:</u>

- The primary HUD tracking task is of sufficiently high workload that the pilots must devote full attention to the head-up display. A high input forcing function bandwidth is desirable in compensatory tracking to produce measurable pilot behavior, and addition of a head-down task produced intolerable pilot workload. In the absence of pilot tracking, it was not uncommon for the pitch/roll error bar to disappear entirely from the HUD, thus making recovery impossible.

- As mentioned above, adding axes to control has the effects expected for divided-attention operations (e.g., Volume II), and therefore the multi-axis data may be interpreted as being representative of divided-attention operations as well. Stated more positively, the data show that multi-axis is tantamount to divided attention for the configurations tested.

Inter- and intra-pilot rating variations for the large pilot population:

- The relative ordering of the configurations (best to worst) was the same for all pilots.

- There is evidence of consistent pilot rating differences between pilots.

- Inter-pilot rating variations were of about the same magnitude as intra-pilot rating variations. For repeat evaluations, all pilots showed consistent intra-pilot rating trends.

Fixed versus moving base comparisons (STI, and LAMARS fixed and moving): Two of the subject pilots were evaluators for the fixed-base simulation at STI and the moving-base simulation on the LAMARS. In addition, both flew a limited series of runs on the LAMARS with the motion drives off. Comparison of their results shows the following:

- The elementary fixed-base simulation conducted at STI was very effective for estimating pilot behavior and performance. The data from this simulation were valid and repeatable, and the simulation provided a means to refine the pre-experimental test plan for the more extensive moving-base simulation.

- There is evidence of divided-attention operation in the fixed-base simulator, but the overall trends differ from the moving-base simulation results. In the fixed-base simulation, run-to-run scatter was higher, and it was not uncommon for the pilots to have better performance (higher crossover frequencies) in both axes for the dual-axis task compared to the single-axis tasks. In compensatory tracking, it is sometimes difficult for the pilots to sort out the sources of displayed error, since it may be due to either the forcing function, pilot control inputs, or both. With motion, the pilot is provided with additional cues as to the source since the aircraft responds only to his control inputs.

- Differences between fixed- and moving base simulations are reflected in the pilot ratings as well. With the LAMARS in fixed-base operation, the pilot ratings compared closely with those for the same configurations from the STI simulator. Addition of motion improved HQRs about one rating point overall, whether compared to the STI simulation or to the LAMARS in fixed-base mode.

For the determination and specification of requirements for minimum flying qualities:

- Pilot ratings for the single-axis baseline configurations were better than predicted by any of the criteria in MIL-STD-1797. This may be a reflection of the conservative nature of the criteria, or of the near-ideal simulation environment (no adverse coupling, no external turbulence, etc.).

- These experiments confirmed the degrading effects of multi-axis operations compared to single-axis. The current military flying qualities specification structure does not recognize this, and needs to be modified.

- For the high-workload multiple-axis tracking tasks used here, combined-axis ratings can be significantly worse than single-axis ratings. The results suggest, for example, that HQRs of 3 for pitch-alone and roll-alone tracking may produce HQRs of 4, 5, or even 6 in the multi-axis case.

- To assure Level 1 flying qualities in both pitch and roll, single-axis HQRs of 2 to 3 are necessary. For Level 2, the single-axis HQRs must be no greater than about 5 to 6. This suggests that for missions involving high workload in both axes (e.g., high-speed terrain following, air combat), in the current specification structure the Level 1 limits in pitch and roll should be based on single-axis HQRs of 2.5 instead of 3.5, and Level 2 limits should be based on HQRs of 5.5 instead of 6.5. Alternatively, the structure of the specifications can be revised to reflect multiple-axis operations.

For the estimation of flying qualities:

- The Optimal Control Model (OCM, Volumes II and III) correctly predicted crossover-model-like pilot-vehicle behavior. There are, however, performance differences overall, and the estimated crossover regions for the pilot-vehicle system are sometimes qualitatively different from that obtained using the classical models (see next conclusion).

- OCM has difficulty estimating pilot behavior for vehicle dynamics where lag generation near crossover is required. This is also an area for which little human operator behavioral data was available, before the present experiment.

- With the exception of the dynamics described above, the OCM estimates of HQRs, both single- and dual-axis, from the cost function, are very accurate.

- The OCM may be used to predict pilot ratings for single- and multiple-axis operations. More work is justified to refine the OCM to make it more generally applicable as a flying qualities tool.

- The Product Rule can be used to estimate multi-axis pilot ratings. The classical Product Rule is generally effective, within a certain range of HQRs (generally about 2 to 8 in each axis). A revised Product Rule that is not subject to these limits has been developed, but it is applicable only to two axes. Further work is required to extend the revised Product Rule to more axes.

- Linear equations for estimating HQRs based on bandwidth parameters (bandwidth frequency and phase delay) proved to be effective. These single-axis equations, produced by linear least-squares fits to the simulation data, can be used in conjunction with the Product Rule to estimate pitch-roll HQRs given only the bandwidths in each axis.

Task differences: Task differences were examined by evaluating several of the tracking cases on visual (terrain-board-referenced) tasks corresponding to pitch-alone (i.e., dolphin), roll-alone (i.e., slalom), and pitch-roll (i.e., combined) HUD tracking. For the visual tasks:

- Pilot-vehicle describing functions were not obtainable, but the pilot ratings provide a cross-check between the HUD tracking and the more real-world maneuvering tasks.

- Since the visual tasks were less constrained, pilot rating scatter is greater. In general, the pilots were not aware of the excessive time delays in pitch, so pilot ratings in pitch were better for the visual tasks. For roll, the slalom involved much larger bank angle commands, leading in some cases to over-controlling and pilot-induced oscillation tendencies, and resulting in general poorer ratings than for the same cases in HUD tracking. The combined-axis ratings were, however, consistent with the pitch-roll tracking ratings.

- Overall, the results of the visual tasks support the conclusions made from the HUD tracking data.

- The tracking task results were more or less bounded by the outside visual tasks, indicating that the tracking task is a reasonable surrogate for the more realistic visual maneuvering. This permits a simpler simulation (rudimentary display), more revealing measurements (e.g., pilot dynamic behavior), and better constraining limits on the subject pilots (because of the forcing function demands) to reveal flying qualities deficiencies.

REFERENCES

1. Military Specification, Flying Qualities of Piloted Airplanes, MIL-F-8785C, Nov. 1980.

2. Military Standard, Flying Qualities of Piloted Vehicles, MIL-STD-1797 (USAF), Mar. 1987.

3. Dander, Vernon A., An Evaluation of Four Methods for Converting Single Axis Pilot Ratings to Multi-Axis Pilot Ratings Using Fixed Base Simulation Data, M.S. Thesis, AFIT GE/EE/62-4, Dec. 1962.

4. McRuer, D., "Human Dynamics in Man-Machine Systems," Automatica, Vol. 16, 1980, pp. 237-253.

5. Cooper, George E., and Robert P. Harper, Jr., The Use of Pilot Rating in the Evaluation of Aircraft Handling Qualities, NASA TN D-5153, Apr. 1969.

6. McRuer, Duane, and David K. Schmidt, "Pilot-Vehicle Analysis of Multi-Axis Tasks," AIAA Guidance, Navigation and Control Conference Proceedings, Aug. 1987, pp. 1312-1327.

7. Ashkenas, Irving L., Roger H. Hoh, and Samuel J. Craig, Recommended Revisions to Selected Portions of MIL-F-8785B(ASG) and Background Data, AFFDL-TR-73-76, Aug. 1973.

8. Neal, T. Peter, and Rogers E. Smith, An In-Flight Investigation to Develop Control System Design Criteria for Fighter Airplanes, AFFDL-TR-70-74, Vol. I, Dec. 1970.

9. Monagan, Stephen J., Rogers E. Smith, and Randall E. Bailey, Lateral Flying Qualities of Highly Augmented Fighter Aircraft, AFWAL-TR-81-3171, June 1982.

10. Smith, Rogers E., and Shahan K. Sarrafian, "Effect of Time Delay on Flying Qualities: An Update," J. Guidance, Control, and Dynamics, Vol. 9, No. 5, Sept.-Oct. 1986, pp. 578-584.

11. Johnston, Donald E., and Bimal L. Aponso, Design Considerations of Manipulator and Feel system Characteristics in Roll Tracking, NASA CR-4111, Feb. 1988.

12. Bailey, Randall E., Bruce G. Powers, and Mary F. Shafer, "Interaction of Feel System and Flight Control System Dynamics on Lateral Flying Qualities," AIAA-88-4327-CP, presented at the AIAA Atmospheric Flight Mechanics Conference, Minneapolis, MN, Aug. 1988.

REFERENCES (CONCLUDED)

13. Chalk, C. R., Recommendations for SCR Flying Qualities Design Criteria, NASA CR-159236, Apr. 1980.

14. Kleinman, D. L., S. Baron, and W. H. Levison, "An Optimal Control Model of Human Response, Part I: Theory and Validation," Automatica, Vol. 6, 1970, pp. 357-369.

15. Thompson, Peter M., "Program CC's Implementation of the Human Optimal Control Model," AIAA-87-2519-CP, presented at the AIAA Guidance, Navigation and Control Conference, Monterey, CA, Aug. 1987.

16. McRuer, D. T., and E. S. Krendel, Mathematical Models of Human Pilot Behavior, AGARD AG-188, Jan. 1974.

17. Hoh, Roger H., David G. Mitchell, Bimal L. Aponso, David L. Key, and Chris L. Blanken, Proposed Specification for Handling Qualities of Military Rotorcraft, Volume II -- Background Information and User's Guide, U. S. Army AVSCOM TR 87-A-3, June 1988.

18. Berry, Donald T., "In-Flight Evaluation of Incremental Time Delays in Pitch and Roll," J. Guidance, Control, and Dynamics, Vol. 9, No. 5, Sept.-Oct. 1986, pp. 573-577.

19. Mitchell, David G., and Roger H. Hoh, "Low-Order Approaches to High-Order Systems: Problems and Promises," J. Guidance, Control, and Dynamics, Vol. 5, No. 5, Sept-Oct. 1982, pp. 482-489.

20. Hoh, Roger H., David G. Mitchell, Irving L. Ashkenas, Richard H. Klein, Robert K. Heffley, and John Hodgkinson, Proposed MIL Standard and Handbook -- Flying Qualities of Air Vehicles, Volume II: Proposed MIL Handbook, AFWAL-TR-83-3081, Vol. II, Nov. 1982.

21. Mitchell, David G., and Roger H. Hoh, Analysis of Industry and Government Comments on Bandwidth, Systems Technology, Inc., TM-1163-1, May 1985.

APPENDIX A

DOCUMENTATION OF FIXED-BASE SIMULATION

A detailed record of the fixed-base simulation performed at Systems Technology, Inc., Hawthorne, CA, during October and November of 1986 is presented in this Appendix.

The intent of this fixed-base study was to make a preliminary assessment of the effects of multiple axis degradations on pilot opinion and performance. It was also used to evaluate the effectiveness of existing criteria for predicting the effects of multiple degradations on pilot opinion. A more comprehensive study on these subjects was performed subsequently on the motion-base simulator (LAMARS) at Wright-Patterson AFB, OH (Appendix B).

In addition to making a preliminary assessment of the effects of multiple axis degradations, this simulation also validated the configurations, task and data gathering methods to be used on the motion-base simulator.

A. SIMULATION OVERVIEW

The fixed-base simulation reported in this Appendix was designed with precision pitch and roll compensatory tracking tasks. As illustrated in Fig. A-1, the aircraft dynamics ($Y_{c\theta}$ and $Y_{c\phi}$) were implemented on an analog computer while the disturbance input generation and data gathering functions were performed by software residing in a digital computer. The pitch and roll loops were independent and there was no inter-axis coupling (Fig. A-1).

The controlling DIGital Describing Function Analyzer (DIGDFA) software computed and output the pitch and roll disturbance functions (θ_I and ϕ_I in Fig. A-1) into the simulation loop. This software also measured, calculated and stored several experimental parameters, including rms and mean magnitudes, time histories of signals, and open- and closed-loop describing functions for the system.

B. MECHANIZATION OF CONTROLLED ELEMENT

The controlled elements were pitch attitude to elevator ($Y_{c\theta}$) and roll attitude to aileron ($Y_{c\phi}$) transfer functions. The transfer function forms for $Y_{c\theta}$ and $Y_{c\phi}$ are given below.

$$Y_{c\theta} = K_{c_\theta} \frac{\omega_{sp}^2 \; (T_{\theta_2} s + 1) \; e^{-\tau_\theta s}}{(s^2 + 2\zeta_{sp} \; \omega_{sp} s + \omega_{sp}^2)}$$

$$Y_{c\phi} = K_{c_\phi} \frac{e^{-\tau_\phi s}}{s \; (T_R s + 1)}$$

The pitch and roll controlled elements were programmed on an analog computer with a second-order Pade approximation model for the time delay.

The transfer function forms of the pitch and roll controlled elements are compatible with the simple transfer function configurations selected for the study (detailed in the main section of this report). In addition to this primary form, additional capability was added in the pitch loop to simulate the k/s, k/s 2, and k/(s-2) controlled elements necessary for comparison of the human pilot crossover model with previous data.

C. DISPLAY AND TASK

The display, shown in Fig. A-2, was a simulation of an Attitude Director Indicator (ADI) with a pitching and rolling horizon implemented on a CRT scope. A fixed aircraft symbol marked the zero attitude error position. A background grid and scale markings provided a means for judging the magnitude of pitch and roll attitude deviations.

The tasks were pitch and roll attitude tracking tasks. The pilots were instructed to minimize the error displayed by the pitching and rolling horizon (i.e., to keep it aligned with the fixed aircraft symbol). Pitch and roll errors were introduced by pseudo-random disturbance signals injected into the outputs of the controlled elements (Fig. A-1).

Desired performance for the task required extended periods of tracking with pitch and roll errors of less than ±1 deg and ±7.5 deg, respectively. Minor excursions beyond these boundaries were permitted for

desired performance if the pilot judged that they were caused by the disturbance function and that recovery was immediate and effective. Adequate performance required pitch and roll errors less than ±2 deg and ±15 deg for the majority of the time.

Single and dual axis evaluations were performed to assess the effects of multi-axis degradations on pilot performance. In single axis evaluations, the dynamics of the axis not being evaluated were frozen with the display showing zero attitude error in that axis.

D. STICK

A McFadden center stick was used for the majority of evaluations. The longitudinal and lateral stick characteristics are shown below. A linear force/displacement gradient was used together with breakout forces of 1.0 lb and 0.5 lb in the longitudinal and lateral axes, respectively. Stick force/displacement gradients and dynamics were verified using X-Y plots of force versus displacement and step responses.

$$\frac{\delta_{e_s}}{F_{e_s}} = \frac{0.2}{\left[\frac{s^2}{(15)^2} + 2\,\frac{(0.7)}{(15)}\,s + 1\right]}\ \frac{\text{inch}}{\text{lb}}$$

$$\frac{\delta_{a_s}}{F_{a_s}} = \frac{0.4}{\left[\frac{s^2}{(16)^2} + 2\,\frac{(0.5)}{(16)}\,s + 1\right]}\ \frac{\text{inch}}{\text{lb}}$$

Stick displacement sensing was used throughout the experiment.

A simple spring-loaded side-stick was used for a limited series of evaluations. The stick characteristics are documented in Ref. A-1.

E. DISTURBANCE INPUT

The pseudo-random pitch and roll disturbance functions were composed of the sum of five sine waves in each axis. The composition of the pitch and roll disturbance functions together with their rms magnitudes and typical signal time histories are presented in Figs. A-3 and A-4.

The frequencies of the disturbance functions were carefully selected

to assure that no harmonics existed, so the signal is non-periodic in appearance (Figs. A-3 and A-4). In addition, there were no common frequencies between the pitch and roll disturbance functions. This allowed the measurement of any possible inter-axis coupling through the stick.

The magnitudes of the sine wave components shown in Figs. A-3 and A-4 represent the compromise achieved in attempting to satisfy two contradictory objectives: 1) high input power for good describing function measurements, and 2) low bandwidth for good pilot crossover characteristics (Ref. A-2). The phasing of the sine wave components in both the pitch and roll disturbance functions was randomly varied to change the time histories of the functions without affecting their spectra or rms magnitudes. This prevented the pilots from "learning" the disturbance functions.

The tracking task lasted approximately 86 sec, of which 73 sec were recorded and analyzed by the DIGDFA software. A "warm-up" and "cool-down" period of 11 and 2 sec, respectively, where no data was recorded, were included at the beginning and end of each run to allow the subject to stabilize his performance before starting the describing function calculations.

The pitch and roll tasks, whether performed separately or combined, were of identical duration.

F. EXPERIMENTAL PROTOCOL

The pilots were provided the controlled element dynamics alone (no forcing function inputs) for a "free" run prior to the formal runs. During these "free" runs, they were allowed to optimize control sensitivity with each configuration before being exposed to the disturbance input. At least two tracking runs were performed with each configuration before assigning a pilot rating and dictating pilot comments. The exception to this rule was pilot H who performed only one run per configuration. The Cooper-Harper handling qualities rating scale was used.

The configurations were presented in a pseudo-random sequence. Single axis evaluations for both pitch and roll were performed first and were followed by dual axis evaluations using various combinations of the single axis configurations Single and dual axis evaluations for a given pilot were performed on the same day to minimize the possibility of day-to-day variations in pilot rating.

In the initial series of runs for a pilot on a given day, configurations were usually presented in increasing order of difficulty in order to "calibrate" the pilot in terms of required compensation. After this initial stage, the configurations were presented in a random order.

G. PILOTS

Pilot H – Engineering Test Pilot and experienced flying qualities evaluation pilot. Holds fixed-wing single and multi-engine and helicopter ratings. He is also a qualified fixed-wing instructor pilot. Flying experience includes over 4000 hours on general aviation aircraft. He has extensive experience on both fixed- and motion-base simulators.

Pilot M – Flying Qualities Engineer and general aviation pilot. Holds single engine fixed-wing rating with 290 hours on general aviation aircraft. Experienced in flying qualities evaluations in both fixed- and moving-base simulations.

Pilot J – Flying Qualities Engineer with previous experience as a military pilot. Previous experience in fixed-base simulators.

All pilots were experienced interpreters of the Cooper-Harper rating scale.

H. CONFIGURATIONS

A complete list of all the pitch and roll controlled elements evaluated in this simulation is presented in Table A-1.

I. RESULTS

A summary of all the pilot ratings for all configurations by all pilots is shown in Fig. A-5. A complete run log is given in Table A-2.

Pilot ratings and performance summaries are presented in Table A-3. The pilot performance measures are based on the human pilot crossover model (Ref. A-2). A listing of these measures together with accompanying explanations are provided below.

The run identifiers in Table A-3 consist of a run number (last three digits consistent with Table A-2) and the date on which the run was performed (first digits). For example, 60333 refers to run number 333 on 6 October (all runs were performed in 1986). Run identifiers with 010___ refer to runs performed on 1 October.

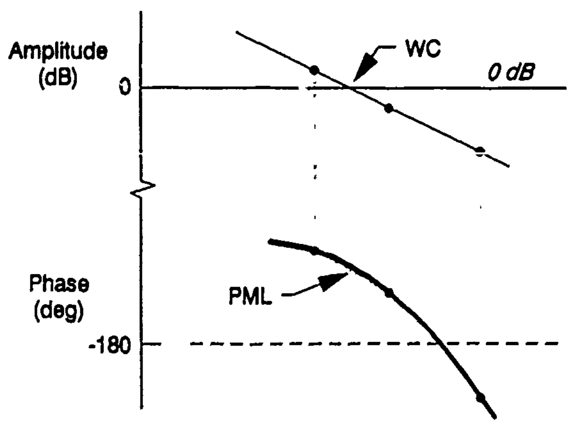
Experimental runs discounted due to equipment failures have not been included in Table A-2 or A-3. These account for any interruptions in the run sequence.

All runs performed in November 1986 (run identifiers with 13N___, 18N___ and 20N___) used the spring loaded stick. All runs performed in October 1986 used the McFadden stick.

The open-loop pilot/vehicle describing functions ($Y_pY_c = \theta/\theta_E$ or ϕ/ϕ_E) for all the experimental runs are listed in Table A-4. The run identifications correspond to the Table A-2 run identifiers.

The open- and closed-loop parameters (Table A-3) extracted from the experimental data are based on the extended crossover model where the plant is assumed to be of the form

$$Y_pY_c\ (j\omega) = \frac{Ke^{-j(\tau_e\omega - \alpha/\omega)}}{j\omega}$$



in the region of crossover. A best "fit" to the describing function amplitude and phase data points for each run is made and the resulting plant and loop closure parameter extracted. These are identified in the table (and sketch) as follows:

- HQR – Cooper-Harper pilot rating given to configuration.
- ESIG – one sigma rms value for tracking error during the run (degrees of pitch or roll tracking error as appropriate).
- CSIG – one sigma rms value for manipulator deflection during the run (inches of longitudinal or lateral stick as appropriate).
- WC – crossover frequency -- frequency of crossover between open-loop 0 dB line and Bode amplitude asymptote calculated from a linear interpolation between the two describing function data points immediately above and below crossover (rad/sec).
- PML – Bode open-loop phase margin at frequency of closed-loop gain crossover, ω_c; computed from a straight line interpolation between the two describing function data points immediately above and below ω_c (deg).
- SLOPE – slope of Bode open-loop amplitude asymptote between two data points immediately above and below gain crossover frequency (dB/decade).
- TE – plant open-loop high frequency time delay parameter from the exponential $\tau\omega$ (sec).
- ALPHA – plant open-loop low frequency phase droop parameter from the exponential α/ω.

REFERENCES

A-1. Teper, Gary L., Richard J. DiMarco, Irving L. Ashkenas, and Roger H. Hoh, Analysis of Shuttle Orbiter Approach and Landing Conditions, NASA CR-163108, July 1981.

A-2. McRuer D. T., and E. S. Krendel, Mathematical Models of Human Pilot Behavior, AGARD-AG-188, Jan. 1974.

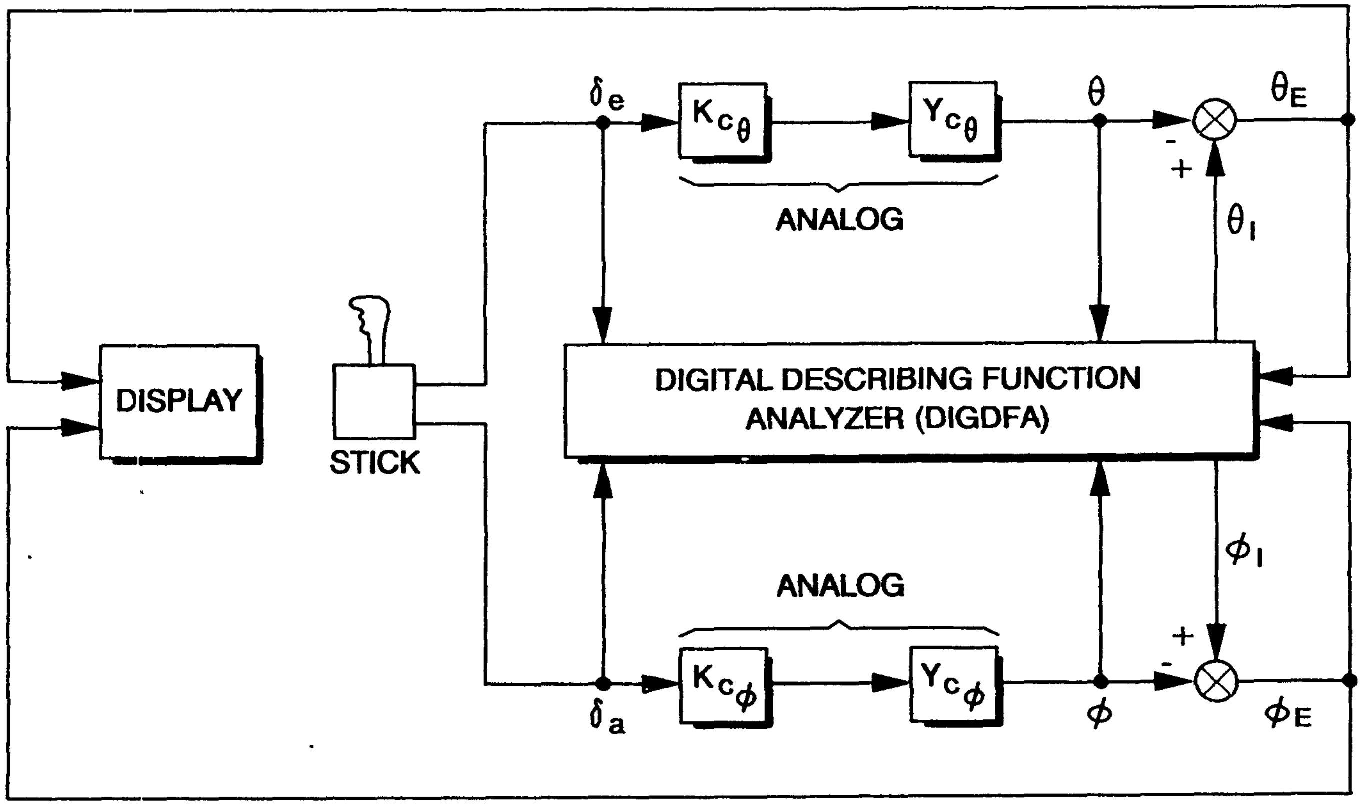


Figure A-1. Fixed-Base Simulator Setup

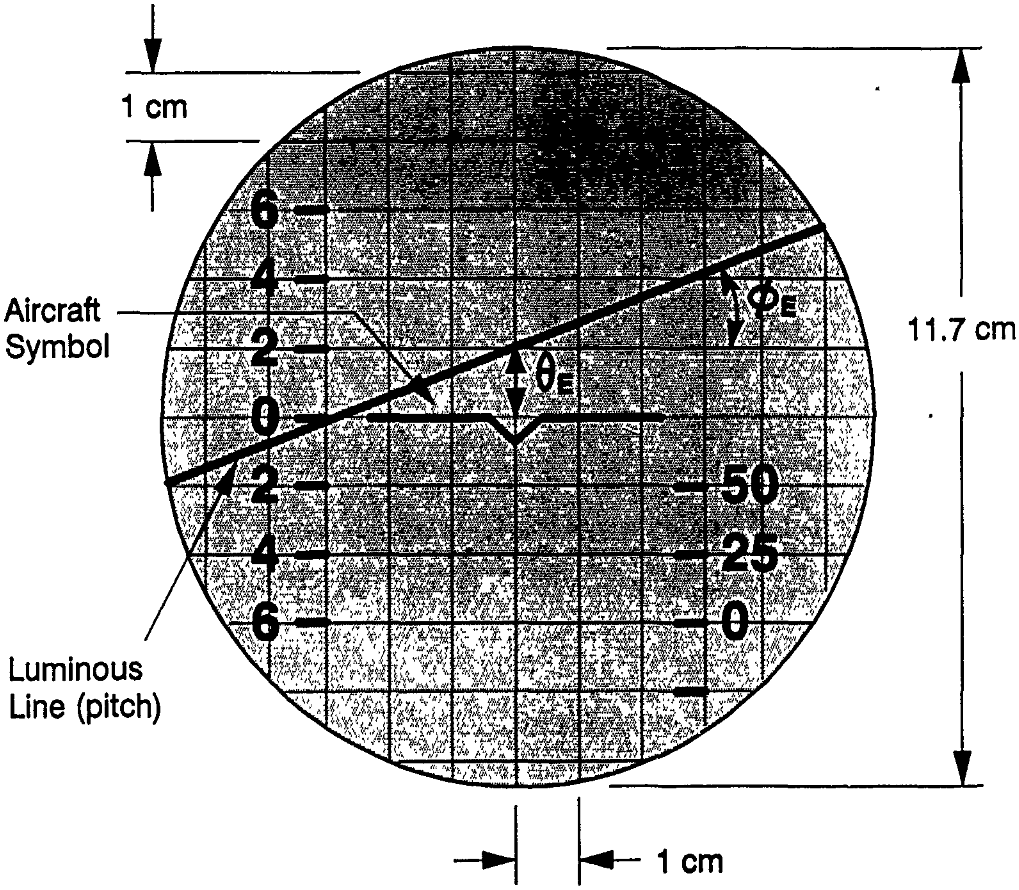
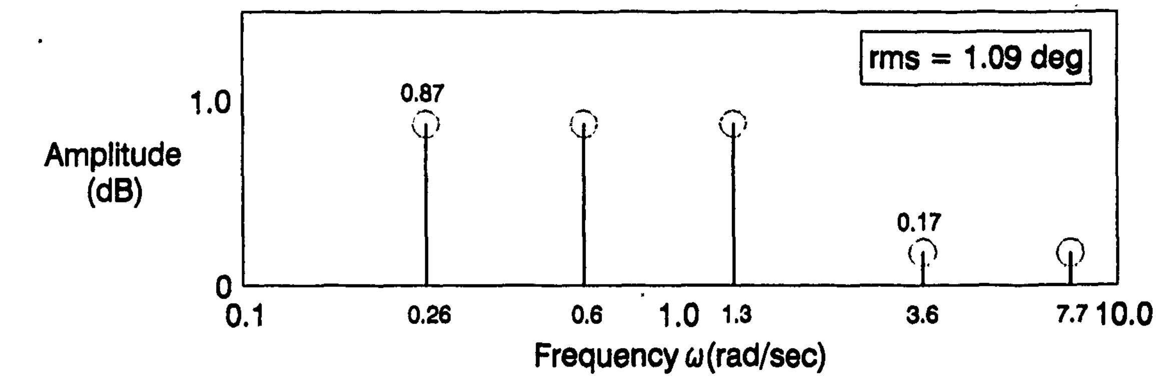
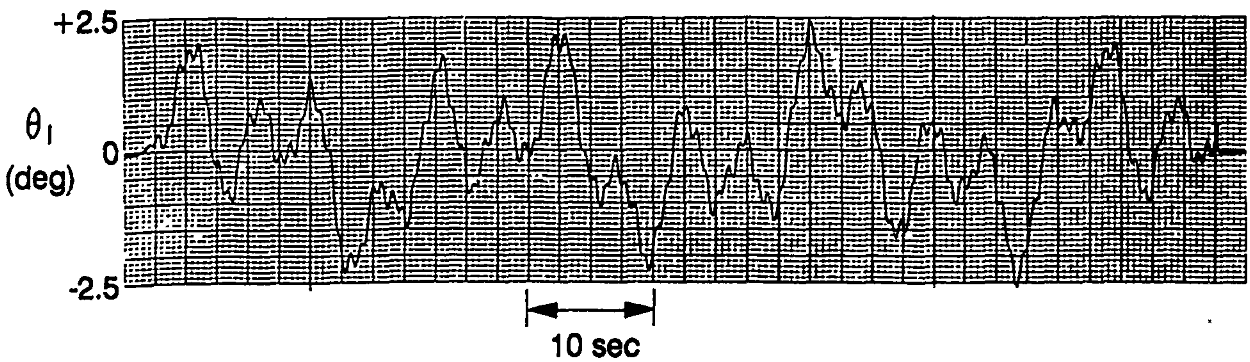


Figure A-2. Display

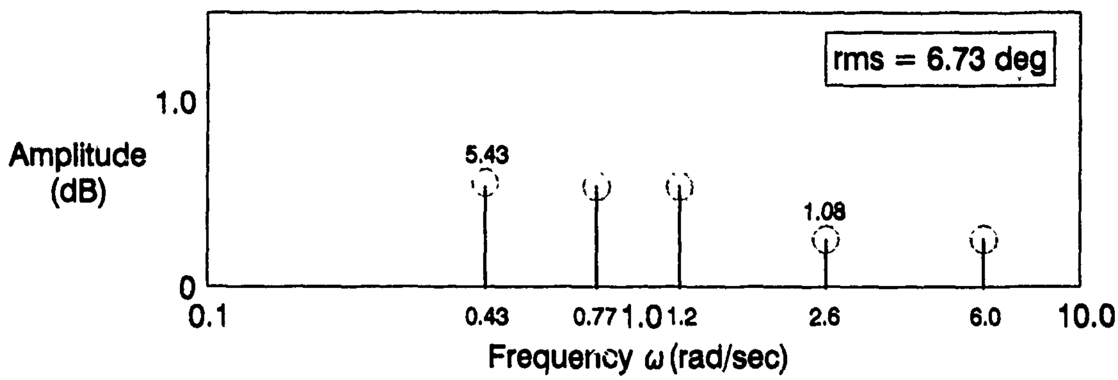


Signal Composition

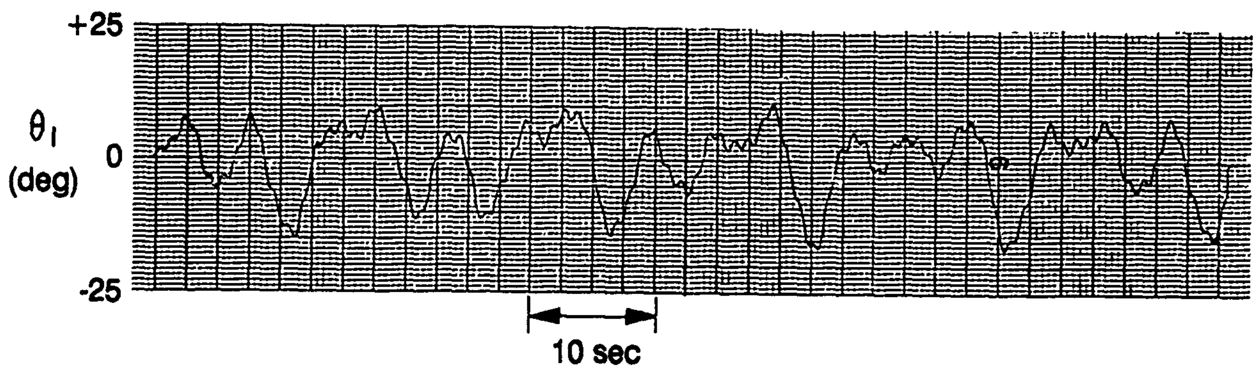


Time History (typical)

Figure A-3. Pitch Attitude Disturbance Function



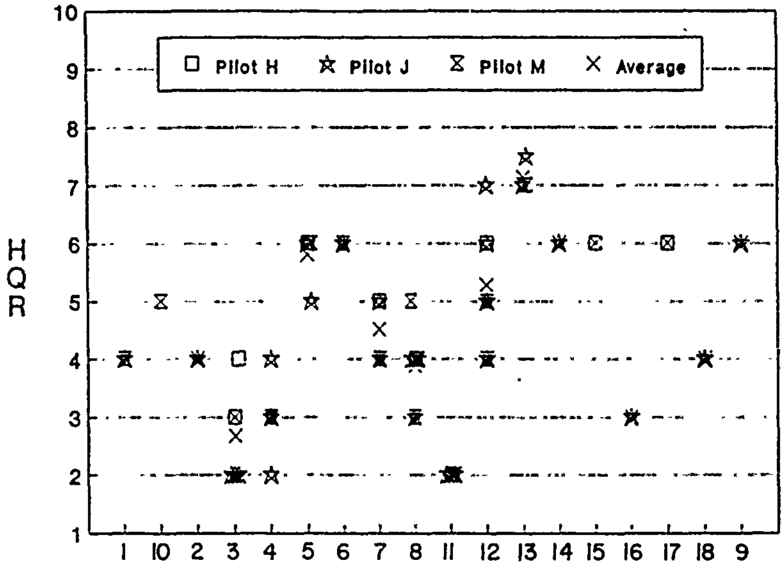
Signal Composition



Time History (typical)

Figure A-4. Roll Attitude Disturbance Function

STI Pitch Cases



STI Roll Cases

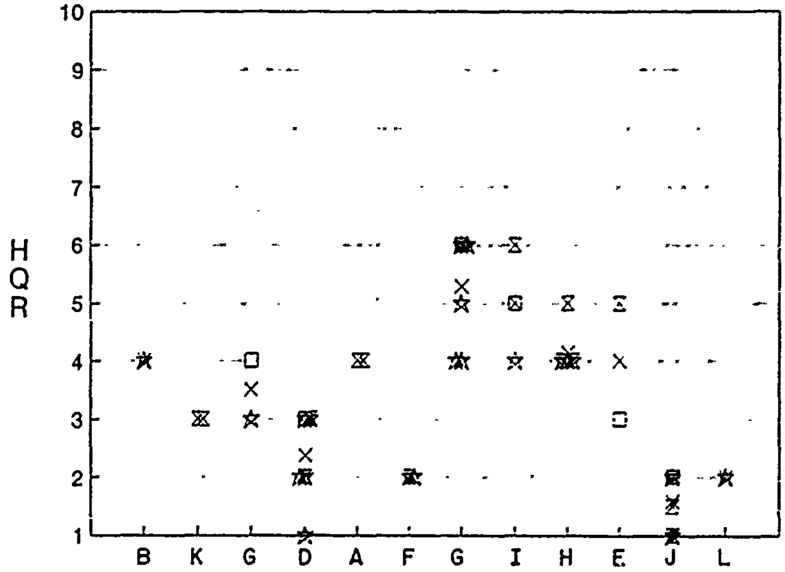
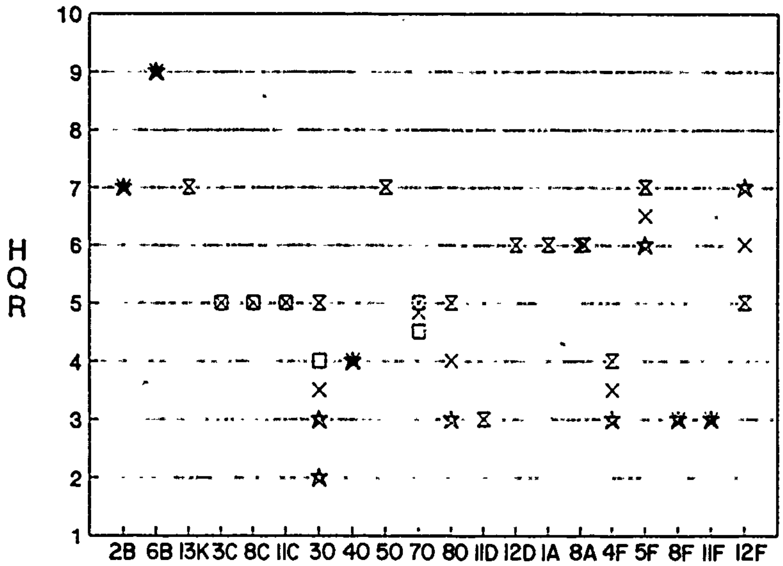


Figure A-5. Pilot Rating Results

STI Pitch/Roll Cases



STI Pitch/Roll Cases

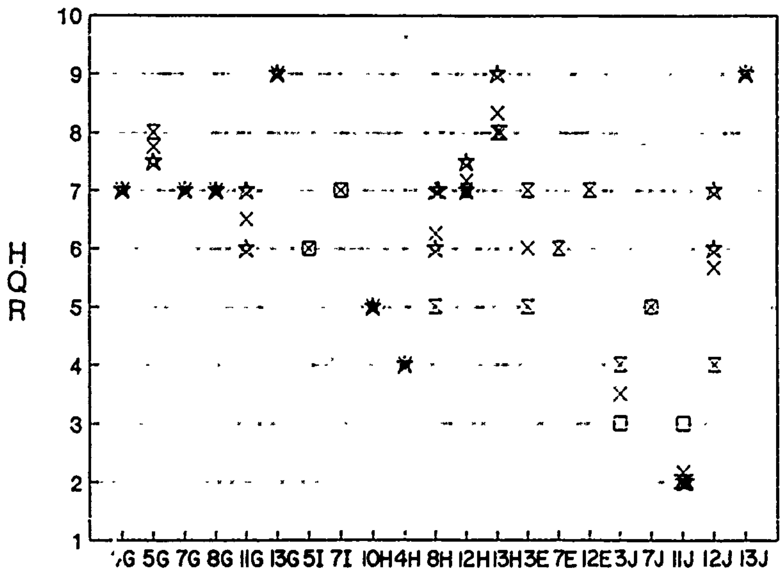


Figure A-5. (Concluded)

TABLE A-1. LIST OF CONFIGURATIONS FOR FIXED-BASE EXPERIMENT

a. Longitudinal Configurations

STI CASE	$Y_c = \frac{\theta}{\delta_e}$
1	$\frac{(0.5)\{.1\}}{(0)[.7,1.0]}$
2	$\frac{(1.25)\{.033\}}{(0)[.2,5.0]}$
3	$\frac{(1.25)\{0.33\}}{(0)[.8,5.0)}$
4	$\frac{(1.25)\{.1\}}{(0)[.8,5.0]}$
5	$\frac{(1.25)\{.2\}}{(0)[.18,5.0]}$
6	$\frac{(1.25)\{.2\}}{(0)[.2,5.0]}$
7	$\frac{(1.25)\{.2\}}{(0)[.5,5.0]}$
8	$\frac{(1.25)\{.2\}}{(0)[.8,5.0]}$
9	$\frac{(1.25)\{.2\}}{(0)[.18,7.0]}$
10	$\frac{(0.5)\{.2\}}{(0)[.7,1.0]}$
11	$\frac{k}{s}$
12	$\frac{k}{s^2}$
13	$\frac{k}{(s-2)}$
14	$\frac{(1.25)\{.2\}}{(0)[.8,1.0]}$
15	$\frac{(1.25)\{.033\}}{(0)[.3,5.0]}$
16	$\frac{(1.25)\{.033\}}{(0)[.5,5.0]}$
17	$\frac{(1.25)\{.2\}}{(0)[.3,5.0]}$
18	$\frac{(1.25)\{.1\}}{(0)[.18,7.0]}$
19	$\frac{(1.25)\{.2\}}{(0)[.8,7.0]}$
20	$\frac{(1.25)\{.033\}}{(0)[.18,5.0]}$
21	$\frac{(1.25)\{.1\}}{(0)[.7,9.7]}$

b. Lateral Configurations

STI CASE	$Y_c = \frac{\phi}{\delta_a}$
A	$\frac{\{.1\}}{(0)(1.0)}$
B	$\frac{\{.067\}}{(0)(.5)}$
C	$\frac{\{.067\}}{(0)(2.0)}$
D	$\frac{\{.067\}}{(0)(4.0)}$
E	$\frac{\{.2\}}{(0)(3.0)}$
F	$\frac{\{.1\}}{(0)(4.0)}$
G	$\frac{\{.2\}}{(0)(0.5)}$
H	$\frac{\{.2\}}{(0)(2.0)}$
I	$\frac{\{.2\}}{(0)(1.0)}$
J	$\frac{k}{s}$
K	$\frac{\{.067\}}{(0)(1.0)}$
L	$\frac{\{.2\}}{(0)(4.0)}$
M	$\frac{\{.067\}}{(0)(5.0)}$

$(a) \equiv (s + a)$

$[\zeta,\omega] \equiv s^2 + 2\zeta\omega s + \omega^2$

$\{\tau\} \equiv e^{-\tau s}$

TABLE A-2. RUN LOG AND SUMMARY OF PILOT COMMENTS FROM FIXED-BASE SIMULATION

NOTE: Pilot comments were not tape-recorded for this experiment; the "Pilot Comments" in this table are taken from the experimenter's notes and are based on the pilots' verbal comments following each run. Runs 1-199 were used for experiment setup and task development; Runs 200 through 226 were used for experimental design and were not included in analysis in this report.

RUN	CONFIG.	PILOT	HQR	PILOT COMMENTS
200	11	J	2	[No comments noted.]
201-202	J		2	[No comments noted.]
203-204	11J		2	Pilot compensation not a factor; control harmony is fine.
205-206	M		2	No difference noted.
207-208	11M		3	Can't keep error low on either task; both about 50% bigger than single axis. Minor excursions, but desired performance.
209	--		--	[Incorrect configuration.]
210-211	K		4	Unresponsive in roll, have to use a lot of stick.
212-213	11K		5	Mainly lateral -- too much stick; errors larger than roll alone.
214-216	12		5	Considerable compensation.
217-218	12K		7	Large amount of lateral stick, difficult to pulse in pitch and hold roll.
219	J		1	Very responsive, easy to handle.
220-221	12J		5	Roll no problem -- pitch nasty.
222-223	13		7	Seemed to be too sensitive.
224	K		5	Lot of stick for control.
225-226	13K		10	Lost it once and almost lost it on other.
227-237	--		--	[Training runs.]
238-239	11	M	2	[No comments noted.]
240-241	3		4	Annoying bobble.
242-243	5		5	Backed off -- no better than 5, almost a 6.
244-246	8		4	Seemed easy but spent too much time outside desired.
247-248	20		6	Initial acceleration high, low damped, got adequate performance.
249-250	12		6	Lots of compensation, almost a 7.
251-252	4		3	More confident about getting desired performance, marginal 3.
253-255	21		3	Very sharp response.

TABLE A-2 (Continued)

RUN	CONFIG.	PILOT	HQR	PILOT COMMENTS
256-257	J	M	1	Stick forces are great, better than longitudinal.
258-259	D		3	Desired performance; really going after it would result in overdriving.
260-261	K		4	Almost desired, but aircraft bad.
262-263	I		6	PIO on first run. Seemed like acceleration command.
264-266	E		4	Lot of work to get desired.
267-268	A		3	[No comments noted.]
269-270	--		--	[Incorrect configuration -- not used.]
271-272	I		5	Almost desired, but dynamics bad.
273-275	11J		4	Even letting pitch go, roll was tough; barely desired in roll -- back off on pitch.
276-278	4D		5	Roll was harder. Pretty busy with stick.
279	11J		4	[No comments noted.]
280	11	H	2	[No comments noted.]
281	3		3	Little sluggish.
282	8		4	Tendency to bobble.
283	5		6	Couldn't tighten up without PIOs.
284	12		6	Very sluggish but adequate performance.
285	17		6	PIO prone.
286	15		6	Performance adequate -- PIO prone.
287	3		4	Slight tendency to PIO around zero.
288	7		5	Lots of tendency to overshoot and bobble.
289	J		2	Good configuration.
290	D		3	[No comments noted.]
291	C		4	Desired performance but sluggish.
292	I		5	Wallows.
293	E		3	Little sluggish.
294	G		6	Sensitivity was low.
295	11J		3	[No comments noted.]
296	3D		4	Both axes about the same, task is demanding. Probably too much high-frequency command.
297-298	3C		5	Torn between 4 and 5. Roll sluggish, more of a problem than pitch.
299	8C		5	Between a 4 and 5. Roll sluggish; pitch no problem.
300	5I		6	Very sluggish in roll, PIO prone in pitch. Barely adequate -- borderline 7.
301	7I		7	Harmony bad -- not enough roll sensitivity. Roll very sluggish.

TABLE A-2 (Continued)

RUN	CONFIG.	PILOT	HQR	PILOT COMMENTS
302	7D	H	5	Not bad in roll -- a little sluggish. PIO prone in pitch -- primary problem.
303	3I		7	Harmony a problem; sluggish in roll.
304	3C		5	Biggest problem: PIO prone in pitch. Sluggish in roll, harmony okay.
305	7D		4.5	Both axes about the same; little sluggish, harmony good. Performance was between desired and adequate.
306	11C		5	Pitch fine, roll sluggish. Terrible harmony.
307	7J		5	Great roll; bad, PIO prone pitch.
308	3J		3	Good pitch, good roll.
309-310	11	J	2	[No comments noted.]
311-312	3		2	Couldn't be as aggressive as last one but still good.
313-314	8		4	Couldn't get it to stop where wanted; not accurate.
315-316	7		4	Oscillatory, difficult to settle down.
317-318	5		6	Able to contain within adequate performance with easy inputs.
319-320	9		6	Adequate performance only.
321-322	19		4	Required moderate compensation, but desired performance; can track inputs.
323-324	12		7	Able to contain it but can't track.
325-326	14		6	Able to just contain within adequate.
327-328	3		2	[No comments noted.]
329-330	12		6	Just a matter of containment.
331-332	4		3	A little twitchy.
333-334	J		2	[No comments noted.]
335-336	D		3	Not as good as previous case.
337-338	C		3	Worked a little bit harder.
339-340	G		6	Just able to contain adequate.
341-342	H		4	[No comments noted.]
343-344	I		4	Kept within desired performance but very easy to get out of phase and PIO.
345-346	D		3	Tendency to oscillate; had to be careful.
347-348	11J		2	[No comments noted.]
349-350	4D		4	Main problem was pitch -- bobbly. Control harmony fine.
351-352	4G		7	Barely controllable. Bobbly pitch, primarily roll problem in terms of damping; harmony bad.
353-354	11G		6	Better pitch -- no problem. Response harmony better.
355-356	8D		3	Harmony good. Undecided between 3 and 4.

TABLE A-2 (Continued)

RUN	CONFIG.	PILOT	HQR	PILOT COMMENTS
357-358	8H	J	7	Adequate performance not attainable, trouble controlling pitch; sluggish roll, but more of a pitch problem.
359-360	4H		4	Pitch no problem; more of a problem in roll.
361-362	12H		7	Close to adequate.
363-364	12J		6	Primarily a pitch control problem -- mostly containment. Control harmony is okay.
365-366	8H		7	Overshoots in pitch, sluggish in roll. More problems in pitch -- roll excites pitch overshoots.
367-368	3D		3	Not much of a problem.
369-370	3	M	3	Had to temper inputs.
371-373	8		4	Seemed sluggish, no precision.
374-375	12		5	Almost worse -- could be a 6.
376-377	7		4	Between 4 and 5 -- not bad enough to be a 5.
378-380	5		6	Sluggish but low-damped; debated between 5 and 6.
381-382	D		2	[No comments noted.]
383-384	K		3	Once familiar with it, easy to get desired performance.
385-386	J		1	Very sure -- looks like ideal.
387-388	I		6	Got adequate performance. Couldn't judge best control technique.
389-390	E		5	Little easier to control -- PIO when tightened up.
391-392	D		3	Not that different from the best case.
393-394	K		3	Marginal 3; more towards 4.
395-396	A		4	Lack of precision; marginal 4, more towards 3.
397-398	11J		2	No compensation, very responsive, harmony good.
399-400	3J		4	Almost a 3; pitch is problem. Got desired, workload in pitch made it a 4. Harmony good.
401-402	3D		5	Wallowy in roll, pitch a little imprecise. A 6 on first run.
403-404	12D		6	Primarily pitch: PIO prone. Roll a little wallowy. Almost not adequate.
405-407	3E		7	Little harsh; pitch not precise, Level 2. But primary difficulty is roll: acceleration-like, very imprecise.
408-410	8A		6	Sluggish in pitch, loose in roll. Roll bigger problem -- looks like an acceleration response.

TABLE A-2 (Continued)

RUN	CONFIG.	PILOT	HQR	PILOT COMMENTS
411-412	8D	M	5	Compromised pitch sensitivity: pitch overshoots, roll sluggish. Both a problem.
413-414	7D		5	Pitch overshoots. Seems sluggish, harder than it should be, in roll.
415-416	7E		6	Pitch looks same as before, roll sluggish and wallowy and more work than pitch.
417-418	5D		7	Temper inputs; PIO prone in pitch, roll a little annoying.
419-420	11D		3	Pitch very precise; roll a little sluggish but easy because of pitch.
421-422	12E		7	Pitch response sluggish and unpredictable; roll a little sluggish.
423-424	3E		5	Almost a 4; pitch is precise, roll is more work.
425-426	13		7	Very squirrely but no worse than 7.
427-428	13K		7	[No comments noted.]
429-469	--		--	[Task development runs.]
470-471	3		2	Tendency to bobble -- had to back off.
472-473	16		3	Tendency to oscillate.
474-475	2		4	Highly oscillatory -- right on border of desired performance.
476-477	8		4	Very similar to previous case.
478-479	7		5	Strong tendency to bobble, almost PIO.
480-481	6		6	Even more bobbly than others; very gentle inputs to get adequate.
482-483	1		4	Got desired performance.
484	13		7	[No comments noted.]
485-486	D		1	[No comments noted.]
487-488	B		4	Sluggish, required pulsing -- able to get desired.
489-490	G		6	Objectionable, but adequate performance.
491	H		4	Seemed like earlier case but with more sensitivity.
492	D		2	Little overshoot -- not bad.
493-494	3D		2	Little bobbly, but desired performance.
495-496	2B		7	Poorly damped in roll, oscillatory in pitch.
497-498	6B		9	Response harmony bad: oscillatory in pitch and wallowy in roll. Controllability marginal.
499-500	8G		7	Wallowy in roll -- primary problem. Pitch not too bad.
501-502	13G		9	Wanted more roll sensitivity, concentrated on pitch. Barely controllable.

TABLE A-2 (Continued)

RUN	CONFIG.	PILOT	HQR	PILOT COMMENTS
503-504	7G	M	7	Adequate performance not obtained; response harmony terrible.
505-506	10H		5	Adequate; pulsing in both axes, so harmony great.
507	11		2	[No comments noted.]
508-509	10		5	Sluggish, can't tighten up; have to pulse and wait. Last run more a 4.
510-511	8		4	Had to hold stick to get steady state.
512-513	6		6	Low damping, very objectionable -- hence rating. Within adequate.
514-515	1		4	Performance not quite desired; lack of precision, looked like time delay.
516	13		7	Outside adequate, always controllable. Learning might make it a 6.
517	J		1.5	[No comments noted.]
518-519	H		5	PIO on first run. Have to use doublets. Could be a 4.5.
520	A		4	Close to desired performance.
521	11J		2	[No comments noted.]
522-523	1A		6	Roll wallowy, pitch okay; pulsing in both axes.
524-526	8A		6	Time delay in pitch, roll ramps off. Solid 6, could not keep pitch error at zero. Control inputs -- pitch single-sided, roll double-sided.
527-528	13H		8	Wasn't real bad but need to let roll go to control pitch.
529	--		--	[No run 529.]
530-531	11	J	2	[No comments noted.]
532-535	--		--	[Mechanization problems -- not used.]
536-537	12		5	Can't track and reduce big excursions; try not to disturb it. Pulse inputs.
538-541	--		--	[Mechanization problems -- not used.]
542-543	13		7	Matter of maintaining control.
544-545	--		--	[Mechanization problems -- not used.]
546-547	J		1	[No comments noted.]
548-549	D		2	Not as good as previous case but still good.
550-551	H		4	Required a lot of lead.
552-553	G		4	Probably a 3 with more control power.
554-555	L		2	Some time delay but no problem.
556-557	G		4	Performance desired; required doublet inputs.
558-559	11J		2	[No comments noted.]
560-562	--		--	[Mechanization problems -- not used.]
563-564	12H		7	Constantly switching between axes.
565-566	11G		7	Can maintain within adequate but can't track.

TABLE A-2 (Continued)

RUN	CONFIG.	PILOT	HQR	PILOT COMMENTS
567-568	13J	J	9	Primarily pitch -- fighting to maintain control. Could pay no attention to roll.
569-570	13H		9	Can lose control in pitch.
571-572	12J		7	Controllability not in question.
573-574	11		2	[No comments noted.]
575-576	4		2	A little more oscillatory.
577-578	8		3	More oscillatory and didn't respond quickly. Borderline between desired and adequate performance.
579-580	5		5	Backed off to keep oscillations down.
581-582	12		4	Requires lots of compensation -- have to lead it.
583-584	4		4	Had to back off to avoid oscillations.
585-586	F		2	Good.
587-588	H		4	Pulsing required.
589-590	G		5	Ran out of control power on large errors.
591-592	F		2	No problem.
593-594	11F		3	Little trouble -- harmony good.
595-596	4F		3	Harmony was good, tracking was almost automatic.
597-598	8H		6	Harmony not good -- quick in pitch and sluggish in roll.
599-600	5G		7.5	Harmony lousy -- had to be smooth in pitch and large pulses in roll.
601-602	5F		6	Mismatch not so bad; smooth in both axes but pitch very oscillatory.
603-604	8F		3	Good harmony; technique was similar in both.
605-606	12F		7	Had to do one axis at a time: big pulses in pitch and little ones in roll.
607	11	M	--	[Practice run.]
608-609	11		2	Not quite a 1.
610-611	4		3	Little lack of precision, not very forgiving.
612-613	12		4	Between 4 and 5 -- desired not quite possible.
614-615	8		5	5 due to PIO tendency, otherwise 4.
616-617	13		7	Solid 7; knew it was unstable but controllable.
618-619	5		6	Learned to temper inputs to keep from exciting it.
620-621	8		3	Marginal 3, not quite precise.
622-623	J		2	Almost a 1, could be 1 with more runs.
624-625	F		2	Feels like k/s.

TABLE A-2 (Concluded)

RUN	CONFIG.	PILOT	HQR	PILOT COMMENTS
626-627	H	M	4	Pulsing technique, doublets. Headed towards a 5 because outside of desired a bit.
628-629	G		6	Required lots of lead; a 5 if more sensitivity available.
630-631	H		4	Marginal Level 2; problem with doublet pulses.
632-633	11J		2	Could be a 3 due to added workload.
634-6[illegible]	[illegible]F		4	Not really bad in either axis, but pitch more critical due to bobble.
636 [illegible]	[illegible]F		7	Can control by backing off in pitch. Roll was swamped by pitch problems.
63[illegible]	12H		7	Harsh, requires pulses in both pitch and roll. May be 6 with better stick.
64 641	8H		5	Pitch okay, trouble in roll. Rating due mainly to workload in roll.
642-643	12J		4	Couldn't keep pitch where wanted.
644-645	5G		8	Can't close pitch loop, low damping very objectionable. Roll sluggish, too much rate buildup causes problems in roll.
646-647	13H		8	Busy in both axes just trying to control. No worse than 8.
648-649	12F		5	Closing the loop in pitch didn't seem to help, pitch didn't seem to respond; roll also not responsive.

TABLE A-3. EXPERIMENTAL RESULTS

PILOT J

RUN	CONFIGURATION		HQR	PITCH LOOP							ROLL LOOP						
	PITCH	ROLL		ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA
010200	11	---	2.0	0.46	0.3	2.62	39.22	-24.6	0.28	0.16							
010201	---	J	2.0								2.64	0.75	2.36	44.3	-27.7	0.3	0.14
010202	---	J									2.59	0.76	2.51	43.06	-28.8	0.31	0.11
010203	11	J	2.0	0.49	0.31	2.28	45.01	-25.4	0.25	0.3	2.89	1.06	3.22	22.45	-22.4	0.21	1.32
010204	11	J		0.47	0.34	2.53	38.86	-24.7	0.29	0.19	2.86	0.95	3.05	25.5	-24.5	0.23	1.08
010205	---	M	2.0								3.32	1.21	2.74	15.82	-28.4	0.33	1.01
010206	---	M									3.29	1.12	2.72	17.89	-27.3	0.33	0.9
010207	11	M	3.0	0.54	0.3	2.03	56.45	-20.1	0.25	0.01	4.33	1.45	2.92	5.61	-24.6	0.4	0.67
010208	11	M		0.56	0.26	1.78	64.6	-23.1	0.29	-0.24	4.09	1.2	2.5	18.6	-21.8	0.53	-0.25
010210	---	K	4.0								5.28	2.47	2.01	3.56	-33.5	0.62	0.34
010211	---	K									4.58	2.2	2.07	0.2	-32.8	0.66	0.25
010212	11	K	5.0	0.58	0.35	2.19	62.24	-18.1	0.24	-0.22	8.1	3.76	1.86	20.25	-29.4	0.54	0.25
010213	11	K		0.49	0.33	2.67	49.5	-19.3	0.27	-0.23	6.03	2.89	1.91	12.86	-32	0.74	-0.29
010214	12	---	5.0	1.38	0.83	3.17	11.61	-25.9	0.34	0.68							
010215	12	---		0.79	0.42	2.75	5.29	-27.8	0.37	0.89							
010216	12	---		0.77	0.31	2.42	4.55	-25.4	0.39	0.91							
010217	12	K	7.0	1.17	0.43	2.16	0.23	-33.1	0.37	1.24	5.28	2.67	1.99	19.01	-28.5	0.59	-0.02
010218	12	K		1.18	0.47	2.72	6.52	-32.5	0.33	1.16	5.12	1.98	1.88	21.57	-30.8	0.58	0.04
010219		J	1.0								2.55	0.71	2.63	54.24	-25.3	0.17	0.47
010220	12	J	5.0	0.92	0.4	2.41	1.53	-27	0.39	1.02	3.34	0.76	1.8	75.66	-24.8	0.16	-0.11
010221	12	J		0.95	0.46	2.71	6.94	-25.3	0.34	1.05	3.41	0.76	1.87	62.38	-24.9	0.28	-0.12
010222	13	---	7.0	1.48	0.26	4.47	6.65	-24.1	0.16	2.89							
010223	13	---		1.15	0.21	4.75	9.77	-20	0.15	2.81							
010224	---	K	5.0								5.31	2.59	2.11	3.18	-32.5	0.6	0.36
010225	13	K	10.0	2.33	0.34	3.1	27.49	-8.9	0.22	1.1	8.92	3.21	1.63	15.72	-32.5	0.74	0
010226	13	K		1.64	0.25	4.54	12.83	-19.8	0.12	3.31	6.6	2.28	1.69	10.27	-31	0.71	0.16

TABLE A-3. (Continued)

PILOT M

RUN	CONFIGURATION PITCH	CONFIGURATION ROLL	HQR	PITCH LOOP ESIG	PITCH LOOP CSIG	PITCH LOOP WC	PITCH LOOP PHL	PITCH LOOP SLOPE	PITCH LOOP TE	PITCH LOOP ALPHA	ROLL LOOP ESIG	ROLL LOOP CSIG	ROLL LOOP WC	ROLL LOOP PHL	ROLL LOOP SLOPE	ROLL LOOP TE	ROLL LOOP ALPHA
50238	11	---	2	0.4	0.12	3.39	31.89	-23.1	0.28	0.07							
50239	11	---		0.4	0.12	3.66	32.77	-30.3	0.24	0.42							
50240	3	---	4	0.48	0.11	3.95	18.12	-24	0.31	-0.06							
50241	3	---		0.5	0.11	3.72	23.74	-25.4	0.3	0.16							
50242	5	---	5	0.82	0.16	0.79	97.37	-11.8	0.02	-0.11							
50243	5	---		0.87	0.17	0.87	90.27	-14.4	-0.08	0.05							
50244	8	---	4	0.67	0.12	2.27	45.58	-13.7	0.41	-0.55							
50245	8	---		0.61	0.14	2.86	38.14	-14.2	0.37	-0.6							
50246	8	---		0.65	0.15	2.63	44.14	-11	0.33	-0.37							
50247	20	---	6	0.76	0.17	1.17	93.41	-9.8	-0.01	-0.05							
50248	20	---		0.72	0.17	1.26	91.65	-12.3	0.07	-0.14							
50249	12	---	6	0.72	0.21	2.16	5.29	-32.7	0.37	1.09							
50250	12	---		0.75	0.22	2.28	1	-32.3	0.4	1.06							
50251	4	---	3	0.53	0.16	3.46	35.58	-13.3	0.32	-0.56							
50252	4	---		0.54	0.16	3.51	31.28	-11.6	0.32	-0.33							
50253	21	---	3	0.57	0.18	2.95	44.21	-13.5	0.3	-0.42							
50254	21	---		0.56	0.19	2.46	54.37	-15	0.28	-0.33							
50255	21	---		0.53	0.2	2.85	46.9	-15.7	0.3	-0.43							
50256	---	J	1								2.59	0.73	2.97	29.3	-35.8	0.15	1.7
50257	---	J									2.32	0.68	3.04	25.94	-34.1	0.19	1.46
50258	---	D	3								3.44	1.1	2.66	21.75	-28.4	0.36	0.58
50259	---	D									3.46	1.08	2.78	19.3	-28.3	0.37	0.48
50260	---	K	4								4.03	1.52	2.03	25	-29.1	0.49	0.17
50261	---	K									4.37	2.35	2.55	16.06	-23.9	0.43	0.46
50262	---	I	6								5.17	0.89	2.14	29.2	-18.9	0.43	0.19
50263	---	I									4.81	0.53	1.84	35.23	-17.3	0.47	0.04
50264	---	E	4								4.86	0.49	2.2	34.54	-14	0.46	-0.2
50265	---	E									4.01	0.36	2.07	37.09	-20.5	0.49	-0.3
50266	---	E									3.96	0.37	2.52	28.97	-13.2	0.44	-0.15
50267	---	A	3								4.65	0.46	1.72	34.74	-23.4	0.46	0.19
50268	---	A									3.97	0.51	2.07	23.93	-27.3	0.46	0.29
50269	---	I	NG								12.73	1	20.89	92.84	1.4	0.34	0.21
50270	---	I	NG								5.94	0.5	1.87	29.33	-31.5	0.49	0.13
50271	---	I	5								4.77	0.54	1.97	16.88	-26.9	0.58	0.11
50272	---	I									4.63	0.56	2.11	22.93	-23.7	0.49	0.18
50273	11	J	4	0.47	0.15	3.52	38.47	-21.9	0.24	0.19	3.36	0.42	3.25	33.41	-24.8	0.25	0.36
50274	11	J		0.45	0.15	3.22	43.75	-21.2	0.22	0.19	3.12	0.46	3.05	27.84	-22.7	0.22	1.09
50275	11	J		0.51	0.14	2.81	49.91	-18.9	0.23	0.01	2.8	0.34	2.74	45.97	-23.5	0.22	0.36
50276	4	D	5	0.73	0.2	2.28	62.73	-8.1	0.29	-0.55	5.14	0.77	2.63	15.28	-22	0.39	0.67
50277	4	D		0.56	0.25	3.4	39.61	-7.6	0.31	-0.63	4.12	0.64	2.53	18.45	-20.5	0.5	-0.07
50278	4	D		0.6	0.26	3.81	32.23	-18.8	0.31	-0.72	3.82	0.57	2.48	23.58	-22.4	0.45	0.06
50279	11	J	4	0.5	0.19	3.01	43.61	-26.3	0.25	0.04	3.09	0.36	2.41	47.16	-23.2	0.26	0.23

TABLE A-3. (Continued)

PILOT H

RUN	CONFIGURATION PITCH	CONFIGURATION ROLL	HQR	PITCH LOOP ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	ROLL LOOP ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA
60280	11	---	2.0	0.48	0.17	3.65	31.3	-28	0.24	0.53							
60281	3	---	3.0	0.6	0.23	2.01	61.55	-10.8	0.35	-0.53							
60282	8	---	4.0	0.68	0.36	2.08	55.53	-7.1	0.38	-0.57							
60283	5	---	6.0	0.83	0.37	0.63	93.42	-12.7	0.04	-0.05							
60284	12	---	6.0	0.73	0.4	2.3	1.68	-28.1	0.4	1.01							
60285	17	---	6.0	0.83	0.4	0.68	86.74	-11.5	0.16	-0.04							
60286	15	---	6.0	0.71	0.41	0.86	97.68	-8.8	-0.05	-0.07							
60287	3	---	4.0	0.61	0.55	1.68	70.37	-13.2	0.37	-0.54							
60288	7	---	5.0	0.73	0.33	1.24	95.84	-9.6	-0.02	-0.1							
60289	---	J	2.0								3.17	0.31	2.34	51.58	-17.5	0.34	-0.31
60290	---	D	3.0								3.86	0.3	2.37	28.85	-20.9	0.41	0.17
60291	---	C	4.0								4.22	0.33	1.83	40.82	-20.4	0.45	-0.05
60292	---	I	5.0								6.18	0.79	2.01	14.81	-26.9	0.61	0.04
60293	---	E	3.0								4.92	0.38	2.11	26.8	-18	0.51	-0.04
60294	---	G	6.0								7.64	1.21	1.67	8.41	-26.2	0.62	0.48
60295	11	J	3.0	0.48	0.17	3.5	38.15	-17.6	0.27	-0.13	4.72	0.49	1.79	59.51	-15.7	0.16	0.37
60296	3	D	4.0	0.61	0.28	3.44	53.63	-6.1	0.24	-0.69	6.53	0.77	3.49	-3.86	-17.4	0.33	1.18
60297	3	C	5.0	0.63	0.28	1.62	87.67	-9.7	0.27	-0.68	6.31	0.89	2.24	35.45	-32.5	0.42	-0.06
60298				0.62	0.23	1.88	69.03	-9.1	0.29	-0.42	5.86	0.49	1.87	32.28	-21.7	0.53	-0.08
60299	8	C	5	0.71	0.28	1	95.7	-10.7	0.07	-0.17	5.21	0.47	2.16	30.66	-16.4	0.52	-0.28
60300	5	I	6	0.84	0.31	0.48	97.16	-18.8	-0.35	0.03	9.08	0.8	1.85	-1.99	-25.8	0.75	0.22
60301	7	I	7	0.71	0.36	1.05	100.4	-14.4	0.04	-0.22	6.86	0.81	1.71	18.11	-29.2	0.56	0.37
60302	7	D	5	0.8	0.36	0.88	94.12	-13.9	-0.01	-0.05	7.1	0.63	2.03	34.92	-6.9	0.46	-0.03
60303	3	I	7	0.79	0.22	0.76	86.57	-8.3	-0.3	0.19	12.61	1.05	1.37	41.8	-22.4	0.41	0.34
60304	3	C	5	0.69	0.21	1.42	85.74	-6.3	0.26	-0.43	6.43	0.52	2.07	24.63	-15.5	0.44	0.35
60305	7	D	4.5	0.8	0.33	0.95	102.24	-16.4	-0.23	0.02	5.9	0.57	1.78	50.54	-21.3	0.57	-0.65
60306	11	C	5	0.53	0.13	2.02	56.27	-25.4	0.25	0.02	5.02	0.36	1.79	33.82	-22.6	0.49	0.08
60307	7	J	5	0.76	0.31	0.73	95.03	-8	-0.13	0.01	4.8	0.45	1.83	74.8	-2.5	0.06	0.24
60308	3	J	3	0.55	0.26	2.37	67.08	-11.1	0.25	-0.57	4.15	0.43	2.26	65.79	-14.3	0.15	0.16

TABLE A-3. (Continued)

PILOT J

RUN	CONFIGURATION		HQR	PITCH LOOP							ROLL LOOP						
	PITCH	ROLL		ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA
60309	11		2.0	0.46	0.44	2.75	34.51	-24.3	0.28	0.29							
60310	11			0.39	0.26	3.63	31.71	-28.9	0.19	1.11							
60311	3		2.0	0.46	0.16	3.95	23.68	-26	0.28	-0.04							
60312	3			0.48	0.16	3.91	24.73	-26.2	0.29	-0.12							
60313	8		4.0	0.75	0.14	3.08	36.14	-11.4	0.35	-0.58							
60314	8			0.66	0.11	2.91	36.16	-8.9	0.36	-0.48							
60315	7		4.0	0.7	0.09	2.35	58.88	-5.8	0.3	-0.51							
60316	7			0.64	0.08	2.29	62.31	-5.9	0.3	-0.57							
60317	5		6.0	0.95	0.07	0.99	83.66	-14.4	0.14	-0.03							
60318	5			0.88	0.06	1.01	84.34	-14	0.16	-0.07							
60319	9		6.0	0.85	0.08	1.57	63.78	-13.6	0.23	0.09							
60320	9			0.85	0.07	1.1	74.09	-16	0.1	0.17							
60321	19		4.0	0.74	0.08	1.66	51.67	-10.9	0.38	-0.07							
60322	19			0.62	0.08	2.14	51.09	-11.6	0.31	-0.14							
60323	12		7.0	1.36	0.35	1.59	24.81	-26.6	0.39	0.67							
60324	12			1.2	0.39	1.7	1.54	-35.2	0.46	1.04							
60325	14		6.0	0.82	0.33	1.78	9.68	-29.2	0.67	0.08							
60326	14			0.94	0.39	1.73	9.17	-30.5	0.69	0.09							
60327	3		2.0	0.49	0.15	3.63	33.14	-23.8	0.29	-0.19							
60328	3			0.48	0.14	3.28	37.72	-13.4	0.31	-0.39							
60329	12		6.0	0.75	0.19	2.34	2.4	-30	0.42	0.87							
60330	12			0.79	0.22	2.44	-0.51	-27.9	0.42	0.93							
60331	4		3.0	0.56	0.09	3.65	29.8	-22.7	0.32	-0.41							
60332	4			0.56	0.1	3.51	32.2	-10.6	0.31	-0.34							
60333		J	2.0								2.55	0.16	2.63	46.32	-26.2	0.17	0.82
60334		J									2.81	0.18	2.5	43.79	-23.3	0.31	0.06
60335		D	3.0								3.65	0.24	2.38	24.74	-25.4	0.48	-0.04
60336		D									3.67	0.22	2.19	28.51	-23.6	0.47	0
60337		C	3.0								4.07	0.29	2.02	22.3	-27.3	0.56	-0.05
60338		C									3.97	0.26	1.96	23.99	-28	0.57	-0.07
60339		G	6.0								7.07	1.48	2.03	8.16	-26.3	0.63	0.16
60340		G									6.66	1.51	2	14.04	-26	0.56	0.25
60341		H	4.0								4.19	0.48	2.68	15.84	-13.1	0.51	-0.29
60342		H									4.56	0.47	2.56	19.47	-21.3	0.55	-0.44
60343		I	4.0								4.94	0.66	2.02	28.33	-17.8	0.56	-0.22
60344		I									4.81	0.67	2.2	25.71	-22.6	0.53	-0.18
60345		D	3.0								3.29	0.28	2.61	29.56	-21.7	0.34	0.41
60346		D									3.05	0.26	2.87	18.15	-31	0.34	0.62
60347	11	J	2.0	0.55	0.21	2.16	51.39	-21	0.24	0.18	3.2	0.26	2.97	22.69	-20.9	0.23	1.26
60348	11	J		0.47	0.23	2.55	44.46	-22.8	0.25	0.17	2.85	0.25	3.27	17.68	-24.6	0.25	1.2
60349	4	D	4.0	0.68	0.12	2.87	36.51	-11.7	0.37	-0.55	5.44	0.33	2.24	19.57	-21.7	0.53	-0.03
60350	4	D		0.59	0.12	4.26	14.06	-13	0.33	-0.64	4.54	0.3	2.39	22.85	-21.8	0.53	-0.29
60351	4	G	7.0	0.76	0.11	1.55	94.17	-11.4	0.38	-1.05	9.33	1.08	1.57	8.63	-20.1	0.81	0.09
60352	4	G		0.8	0.12	1.79	75.74	-5.8	0.3	-0.50	7.61	0.98	1.69	0.62	-24.5	0.77	0.25
60353	11	G	6.0	0.74	0.16	0.93	85.18	-14.2	-0.04	0.11	8.75	1.22	1.71	6.6	-27.2	0.77	0.08
60354	11	G		0.6	0.19	1.45	88.51	-21.4	0.25	-0.5	6.06	0.97	1.86	5.54	-23.5	0.66	0.26
60355	8	D	3.0	0.73	0.18	2.66	39.44	-7.4	0.37	-0.43	4.62	0.36	2.56	24.76	-16.9	0.47	-0.17
60356	8	D		0.67	0.19	3.02	34.34	-12.1	0.37	-0.61	3.83	0.26	2.47	23.71	-18.7	0.53	-0.4
60357	8	H	7.0	0.78	0.11	2.17	69.34	-5.4	0.34	-0.89	7.01	0.59	2.05	20.2	-14.2	0.65	-0.37
60358	8	H		0.77	0.12	2.58	50.32	-2.9	0.37	-0.85	5.51	0.4	1.92	30.65	-17.9	0.66	-0.62
60359	4	H	4.0	0.6	0.11	3.93	25.34	-10.1	0.33	-0.89	5.54	0.36	1.82	25.59	-18.9	0.7	-0.42
60360	4	H		0.61	0.11	3.55	47.85	-8.4	0.24	-0.38	5.46	0.35	1.88	23.13	-19.5	0.69	-0.37
60361	12	H	7.0	0.99	0.19	1.75	13.8	-26.4	0.47	0.64	5.98	0.47	2.13	25.65	-15.9	0.62	-0.51
60362	12	H		0.87	0.21	2.16	14.75	-25.4	0.32	0.99	4.98	0.47	2.46	20.73	-9.2	0.58	-0.58
60363	12	J	6.0	0.94	0.23	2.14	9.16	-29.6	0.32	1.2	3.94	0.22	2.14	78.96	-8.8	0.14	-0.24
60364	12	J		0.86	0.23	2.25	-3.64	-30.3	0.43	1.05	3.35	0.18	2.35	57.73	-17.9	0.27	-0.23
60365	8	H	7.0	0.82	0.12	0.93	115.28	-11.4	-0.3	-0.12	5.29	0.3	1.72	32.89	-19.5	0.63	-0.26
60366	8	H		0.76	0.11	1.18	95.32	-13.8	-0.03	-0.06	6.55	0.44	2	16.38	-19.7	0.59	0.07
60367	3	D	3.0	0.57	0.14	2.53	59.89	-9.3	0.26	-0.48	4.35	0.31	2.74	13.6	-23.6	0.41	0.47
60368	3	D		0.55	0.14	2.79	55.45	-10.8	0.25	-0.38	4.23	0.26	2.58	20.91	-24.7	0.45	0.14

TABLE A-3. (Continued)

PILOT M

RUN	CONFIGURATION PITCH	CONFIGURATION ROLL	HQR	PITCH LOOP ESIG	PITCH LOOP CSIG	PITCH LOOP WC	PITCH LOOP PML	PITCH LOOP SLOPE	PITCH LOOP TE	PITCH LOOP ALPHA	ROLL LOOP ESIG	ROLL LOOP CSIG	ROLL LOOP WC	ROLL LOOP PML	ROLL LOOP SLOPE	ROLL LOOP TE	ROLL LOOP ALPHA
70369	3	---	3.0	0.53	0.17	3.34	34.14	-13.9	0.32	-0.44							
70370	3	---		0.53	0.16	3.45	29.91	-14	0.33	-0.36							
70371	8	---	--	0.69	[illegible]	2.28	53.27	-9.2	0.38	-0.66							
70372	8	---	--	0.7	0.13	1.9	68.27	-6.9	0.37	-0.73							
70373	8	---	4.0	0.63	0.15	1.93	65.6	-8.7	0.37	-0.69							
70374	12	---	5.0	0.74	0.2	2.17	-0.43	-32.2	0.36	1.33							
70375	12	---		0.73	0.2	2.27	-3.97	-31.1	0.4	1.25							
70376	7	---	4.0	0.67	0.19	1.96	59.14	-7.1	0.35	-0.42							
70377	7	---		0.71	0.19	1.92	57.03	-8.4	0.38	-0.45							
70378	5	---	--	0.91	0.28	0.51	99.62	-21.8	-0.47	0.04							
70379	5	---	6.0	0.8	0.32	0.87	87.38	-17.2	0.11	-0.05							
70380	5	---		0.81	0.34	0.96	86.08	-15.5	0.17	-0.09							
70381	---	D	2.0								3.64	0.46	2.15	33.04	-22.1	0.45	-0.05
70382	---	D									3.5	0.43	2.1	40.36	-21.5	0.42	-0.13
70383	---	K	3.0								4.35	0.66	1.77	31.64	-26	0.43	0.17
70384	---	K									4.1	0.77	1.93	25.96	-26.8	0.5	0.17
70385	---	J	1.0								2.8	0.31	2.48	59.64	-21.4	0.24	-0.16
70386	---	J									2.56	0.22	3.26	25.83	-28.6	0.17	1.61
70387	---	I	6.0								5.3	0.68	1.89	25.64	-23.1	0.49	0.22
70388	---	I									5.01	0.64	1.9	28.36	-17.8	0.49	0.14
70389	---	E	5.0								4.3	0.42	2.15	37.6	-15.1	0.48	-0.32
70390	---	E									4.2	0.48	2.61	32.6	-22.2	0.47	-0.59
70391	---	D	3.0								3.87	0.42	1.94	45.36	-21.9	0.43	-0.19
70392	---	D									3.73	0.43	2.16	38.03	-18.7	0.41	-0.02
70393	---	K	3.0								4.49	0.93	2.12	27.21	-22	0.5	-0.04
70394	---	K									4.07	0.7	2.27	27.31	-22.6	0.44	0.15
70395	---	A	4.0								4.32	0.66	2.1	27.49	-20.6	0.46	0.14
70396	---	A									4.05	0.7	2.21	27.37	-22.2	0.49	-0.05
70397	11	J	2.0	0.45	0.21	2.91	39.46	-28.4	0.26	0.15	2.72	0.44	3.16	23.83	-28.1	0.23	1.06
70398	11	J		0.45	0.22	2.97	41.59	-23.7	0.25	0.14	2.6	0.5	3.34	21.59	-28.6	0.24	1.06
70399	3	J	4.0	0.51	0.31	3.09	42.08	-14.6	0.31	-0.47	2.97	0.48	2.88	24.94	-23	0.24	1.16
70400	3	J		0.51	0.32	3.14	43.43	-15.7	0.29	-0.44	2.84	0.47	3.09	26	-26.4	0.23	1.03
70401	3	D	5.0	0.67	0.34	2.11	64.51	-9.1	0.28	-0.43	5.44	0.34	2.75	17.46	-20.7	0.36	0.65
70402	3	D		0.57	0.3	2.09	77.61	-10.7	0.21	-0.53	4.38	0.63	2.58	21.5	-18.7	0.51	-0.33
70403	12	D	6.0	0.66	0.49	2.49	1.74	-35	0.37	1.15	3.89	0.7	3.27	3.02	-22.6	0.41	0.25
70404	12	D		0.76	0.61	2.44	12.03	-25.4	0.36	0.81	4.14	0.65	2.48	36.49	-21.2	0.37	0.01
70405	3	E	--	0.73	0.37	2.1	76.97	-5.2	0.18	-0.39	6.85	0.69	2.11	21.54	-21.5	0.67	-0.58
70406	3	E	7.0	0.62	0.33	2.24	71.28	-8.2	0.21	-0.43	5.65	0.62	2.15	23.56	-18.3	0.53	-0.07
70407	3	E		0.64	0.34	2.25	78.54	-7.6	0.19	-0.56	5.12	0.66	2.22	20.68	-16.3	0.48	-0.08
70408	8	A	6.0	0.77	0.45	1.87	75.98	-5	0.29	-0.62	5.56	0.82	2.05	19.5	-35.8	0.54	0.1
70409	8	A		0.75	0.47	1.26	89.2	-19.6	-0.07	0.13	5.66	0.8	2.02	16.15	-24	0.59	0.06
70410	8	A		0.74	0.43	1.48	80.48	-5.7	0.34	-0.53	5.1	0.67	2.04	5.89	-26.5	0.61	0.28
70411	8	D	5.0	0.68	0.43	2.1	50	-11.7	0.35	-0.25	3.61	0.51	2.59	23.69	-24.8	0.43	0.09
70412	8	D		0.71	0.42	2.07	57.71	-10.5	0.33	-0.37	4.12	0.47	2.22	29.58	-22.4	0.48	-0.1
70413	7	D	5.0	0.74	0.32	1.22	91.09	-14.2	-0.04	0.04	4.48	0.5	2.47	25.34	-17.9	0.51	-0.34
70414	7	D		0.7	0.32	1.99	58.89	-8.9	0.33	-0.37	3.73	0.43	2.58	23.21	-21.7	0.46	-0.04
70415	7	E	6.0	0.75	0.43	1.09	87.62	-13.1	-0.09	0.15	5.34	0.56	2.09	24.01	-23.1	0.58	-0.23
70416	7	E		0.69	0.4	1.01	93.83	-16.9	-0.1	0.04	5.36	0.61	2.28	22.25	-15.8	0.57	-0.36
70417	5	D	7.0	0.86	0.52	1.11	75.42	-14.1	0.23	-0.02	5.81	0.52	2.13	26.38	-24	0.5	-0.01
70418	5	D		0.83	0.48	1.01	78.46	-14.1	0.07	0.12	5.87	0.5	2.04	27.76	-19.9	0.52	-0.06
70419	11	D	3.0	0.48	0.24	2.74	38.58	-27.7	0.26	0.3	3.38	0.37	2.47	27.95	-25.9	0.45	-0.1
70420	11	D		0.44	0.24	2.69	44.68	-27	0.24	0.21	3.35	0.41	3.08	14.9	-19	0.36	0.35
70421	12	E	7.0	0.79	0.55	2.25	4.21	-28.8	0.36	1.16	5.38	0.61	2.51	17.23	-17.8	0.54	-0.24
70422	12	E		0.86	0.7	2.41	3.55	-26.1	0.34	1.23	5.74	0.71	2.82	5.45	-18.9	0.52	-0.11
70423	3	E	5.0	0.58	0.3	2.07	63.9	-14.6	0.28	-0.38	5.1	0.55	2.33	22.92	-15.7	0.51	-0.1
70424	3	E		0.62	0.32	2.21	64.53	-13.1	0.27	-0.43	5.41	0.51	2.16	22.11	-19.3	0.57	-0.22
70425	13	---	7.0	1.55	0.21	3.7	17.49	-19.8	0.2	1.86							
70426	13	---		1.39	0.33	4.31	11.91	-21.2	0.18	2.29							
70427	13	K	7.0	1.33	0.37	4.76	11.47	-17.2	0.16	2.39	5.26	0.88	1.96	19.38	-23.5	0.53	0.26
70428	13	K		1.27	0.34	4.4	14.85	-14.7	0.16	2.3	5	0.85	2.01	15	-25	0.51	0.4

TABLE A-3. (Continued)

PILOT J

RUN	CONFIGURATION PITCH	CONFIGURATION ROLL	HQR	PITCH LOOP ESIG	PITCH LOOP CSIG	PITCH LOOP WC	PITCH LOOP PML	PITCH LOOP SLOPE	PITCH LOOP TE	PITCH LOOP ALPHA	ROLL LOOP ESIG	ROLL LOOP CSIG	ROLL LOOP WC	ROLL LOOP PML	ROLL LOOP SLOPE	ROLL LOOP TE	ROLL LOOP ALPHA
90470	3	---	2	0.51	0.15	3.62	31.5	-26.6	0.3	-0.2							
90471	3	---		0.48	0.15	3.64	30.08	-28.2	0.28	0.02							
90472	16	---	3	0.49	0.14	3.65	29.56	-28	0.29	-0.05							
90473	16	---		0.47	0.13	3.77	30.93	-29.5	0.31	-0.63							
90474	2	---	4	0.64	0.12	2.87	56.23	-9.5	0.19	-0.01							
90475	2	---		0.67	0.11	2.23	73.27	-9.4	0.12	0							
90476	8	---	4	0.64	0.1	2.49	41.54	-13.1	0.36	-0.33							
90477	8	---		0.64	0.1	2.78	37.5	-10.4	0.35	-0.33							
90478	7	-	5	0.64	0.09	3.21	29.17	-10.6	0.34	-0.21							
90479	7	---		0.65	0.09	2.67	38.7	-12.9	0.34	-0.26							
90480	6	---	6	0.77	0.08	2.65	52.59	-4.2	0.27	-0.29							
90481	6	---		0.63	0.08	2.71	45.24	-9.2	0.29	-0.2							
90482	1	---	4	0.61	0.17	1.87	30.87	-29.5	0.48	0.03							
90483	1	---		0.6	0.18	2.22	14.42	-30.6	0.53	-0.04							
90484	13	---	7	1.33	0.32	3.02	12.51	-14.6	0.26	1.46							
90485	---	D	1								3.45	0.25	2.42	26.77	-23.5	0.44	0.04
90486	---	D									3.48	0.22	2.18	30.13	-27.1	0.45	0.03
90487	---	B	4								5.95	1.04	1.75	15.87	-32.4	0.48	0.63
90488	---	B									4.74	1.03	1.98	10.41	-32.3	0.51	0.59
90489	---	G	6								7.63	2	2.11	11.55	-20.6	0.56	0.25
90490	---	G									5.89	1.12	1.69	18.07	-22	0.62	0.21
90491	---	H	4								4.58	0.39	1.87	40.31	-15.2	0.52	-0.32
90492	---	D	2								3.07	0.25	2.65	24.13	-27	0.32	0.8
90493	3	D	2	0.52	0.15	3.47	38.24	-11.8	0.3	-0.49	3.81	0.28	2.43	25.24	-21.9	0.48	-0.14
90494	3	D		0.52	0.15	3.32	46.41	-11.5	0.26	-0.39	3.82	0.26	2.46	24.32	-21.9	0.49	-0.21
90495	2	B	7	1.09	0.11	0.32	103.9	-20.8	-0.24	-0.05	8.05	0.54	1.03	41.16	-35.2	0.84	-0.03
90496	2	B		1	0.09	0.4	97.14	-13.8	-0.49	0.03	7.59	0.5	0.95	50.75	-18	0.75	-0.04
90497	6	B	9	1.14	0.06	0.59	106.31	-19.9	-1.2	0.26	7.77	0.55	1.14	48.29	-4.4	0.57	0.08
90498	6	B		1.13	0.07	0.42	92.3	-27.8	-0.4	0.05	7.48	[illegible]	1.15	40.5	-19.6	0.78	-0.05
90499	8	G	7	0.91	0.1	0.89	92.99	-4	-0.32	0.21	6.61	0.83	1.56	11.21	-24.9	0.76	0.15
90500	8	G		0.8	0.1	1.54	82.22	-22.8	0.4	-0.78	7.76	0.75	1.46	16.79	-26	0.85	-0.05
90501	13	G	9	2.1	0.45	3.56	17.62	-9.9	0.25	1.3	13.66	1.13	1.4	5.78	-20.8	0.96	0.07
90502	13	G		1.64	0.36	2.89	34.2	-16.4	0.15	1.31	8.47	0.95	1.55	-2.72	-28	0.96	0.04
90503	7	G	7	0.84	0.1	1.1	104.62	-8.5	-0.04	-0.22	7.65	0.64	1.23	32.08	-37	0.93	-0.19
90504	7	G		0.88	0.09	1.35	94.69	-9.9	0.29	-0.63	7.49	0.77	1.51	9.37	-25.7	0.84	0.08
90505	10	H	5	0.88	0.17	1.76	19.32	-22.8	0.59	0.1	5.98	0.42	1.72	43.02	-14.2	0.63	-0.55
90506	10	H		0.73	0.2	2.06	13.79	-26.2	0.6	-0.15	4.76	0.29	1.76	35.23	-19	0.6	-0.3

TABLE A-3. (Continued)

PILOT M

RUN	CONFIGURATION PITCH	CONFIGURATION ROLL	HQR	PITCH LOOP ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	ROLL LOOP ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA
90507	11	---	2.0	0.41	0.18	3.51	33.58	-21.9	0.28	-0.02							
90508	10	---	5.0	0.73	0.34	2.33	11.72	-22.9	0.51	0.05							
90509	10	---		0.6	0.19	2.06	14.65	-27.8	0.63	-0.3							
90510	8	---	4.0	0.71	0.24	2.1	41.18	-14.4	0.44	-0.36							
90511	8	---		0.69	0.2	1.78	57.59	-10.6	0.43	-0.47							
90512	6	---	6.0	0.83	0.3	1.07	82.02	-11.1	0.13	-0.01							
90513	6	---		0.79	0.29	1.11	80.41	-11.5	0.16	-0.01							
90514	1	---	4.0	0.56	0.29	2.28	15.04	-30.5	0.49	0.1							
90515	1	---		0.54	0.32	2.56	8.88	-32.7	0.47	0.2							
90516	13	---	7.0	1.01	0.49	4.04	15.86	-20.1	0.17	2.28							
90517	---	J	1.5								2.54	0.39	2.96	48.83	-22.5	0.16	0.65
90518	---	H	5.0								4.84	0.76	1.98	34.44	-20.4	0.47	-0.01
90519	---	H									4.23	0.66	2.07	34.49	-18.9	0.5	-0.22
90520	---	A	4.0								3.69	0.47	2.34	30.88	-20.5	0.44	-0.05
90521	11	J	2.0	0.47	0.19	3.06	40.34	-21.3	0.26	0.09	3.06	0.48	3.06	41.89	-23.5	0.25	0.03
90522	1	A	6.0	0.75	0.49	2.55	25.8	-25.6	0.43	-0.24	4.4	0.73	3.1	2.27	-17.8	0.41	0.48
90523	1	A		0.64	0.38	2.29	28.25	-22.2	0.39	0.12	4.21	0.66	2.4	24.31	-25.3	0.47	0.02
90524	8	A	6.0	0.71	0.35	1.13	91.82	-12	-0.09	0.08	4.37	0.63	2.56	20.25	-18.7	0.49	-0.12
90525	8	A		0.77	0.4	1.15	90.85	-16.9	-0.05	0.04	4.4	0.64	2.48	24.44	-21.2	0.42	0.21
90526	8	A		0.76	0.39	1.32	86.33	-9.3	0.33	-0.5	4.45	0.61	2.24	25.74	-26.8	0.55	-0.32
90527	13	H	8.0	1.48	0.61	3.29	17.04	-11.8	0.23	1.48	7.66	0.98	2.19	14.5	-22.9	0.64	-0.31
90528	13	H		1.48	0.58	3.24	17.96	-11.7	0.26	1.18	6.64	0.8	2.08	18.18	-18.8	0.61	-0.17

TABLE A-3. (Continued)

PILOT J

RUN	CONFIGURATION		HQR	PITCH LOOP							ROLL LOOP						
	PITCH	ROLL		ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA
13N530	11	---	2.0	0.41	0.24	3.2	40.19	-21.8	0.26	0.05							
13N531	11	---		0.42	0.23	2.99	46.02	-20.6	0.24	0.04							
13N536	12	---	5.0	0.9	0.35	2.14	10.67	-26.5	0.34	1.06							
13N537	12	---		0.68	0.31	2.34	2.33	-29.4	0.39	1.05							
13N542	13	---	7.5	1.26	0.23	3.78	19.94	-17.6	0.17	2.09							
13N543	13	---		1.38	0.25	4.19	16.68	-16.2	0.13	2.76							
13N546	---	J	1.0								2.41	0.2	3.14	33.68	-28.4	0.13	1.59
13N547	---	J									2.46	0.19	2.78	43.46	-25.8	0.15	1.07
13N548	---	D	2.0								3.13	0.29	2.8	20.16	-25.5	0.34	0.63
13N549	---	D									3.21	0.25	2.38	30.34	-26.8	0.43	0
13N550	---	H	4.0								4.48	0.35	1.85	30.12	-24	0.55	-0.09
13N551	---	H									4.17	0.43	2.34	25.17	-24.4	0.44	0.19
13N552	---	G	4.0								7.09	1.23	1.74	7.44	-29.5	0.59	0.54
13N553	---	G									6.04	1.06	1.81	3.85	-29.6	0.61	0.52
13N554	---	L	2.0								4.52	0.26	2.14	35.31	-16.1	0.51	-0.4
13N555	---	L									4.17	0.23	2.05	37.74	-17.4	0.45	-0.1
13N556	---	G	4.0								5.73	0.95	1.63	21.93	-24.2	0.59	0.23
13N557	---	G									5.19	0.94	1.79	12.87	-25.6	0.6	0.32
13N558	11	J	2.0	0.57	0.23	2	51.04	-22.9	0.25	0.19	3.02	0.24	3.4	34.68	-24.5	0.21	0.56
13N559	11	J		0.53	0.23	2.19	46.58	-23	0.28	0.12	3.23	0.24	2.8	31.19	-19.4	0.21	1.15
13N563	12	H	7.5	1.44	0.39	1.59	27.98	-16.2	0.31	0.8	6	0.53	1.77	41.31	-16.3	0.56	-0.33
13N564	12	H		1.2	0.39	2.06	8.83	-23.4	0.37	1.02	5.36	0.46	1.87	26.57	-21	0.64	-0.28
13N565	11	G	7.0	0.74	0.2	1.05	96.28	-13.8	-0.11	0.01	8.68	0.89	1.19	38.61	-14.4	0.7	0.08
13N566	11	G		0.75	0.19	0.9	88.04	-10.6	-0.04	0.06	7.36	0.88	1.41	28.78	-19.2	0.63	0.17
13N567	13	J	9.0	1.51	0.3	4.05	14.7	-24.5	0.14	2.91	4.13	0.21	1.8	69.37	-15.6	0.26	-0.24
13N568	13	J		1.64	0.31	4.72	11.79	-17.4	0.16	2.53	4.88	0.17	1.09	101.92	-18.5	-0.08	-0.13
13N569	13	H	9.0	2.03	0.33	3.83	15.73	-13.9	0.16	2.56	8.47	0.64	1.77	19.37	-19.8	0.55	0.3
13N570	13	H		1.54	0.27	3.78	25.3	-17.8	0.19	1.54	6.2	0.35	1.52	31.23	-18.8	0.76	-0.29
13N571	12	J	7.0	1.45	0.44	1.97	4.35	-26.5	0.41	1.02	4.46	0.28	1.16	98.85	-35.3	-0.25	0.15
13N572	12	J		1.42	0.52	2.16	-1.98	-22.2	0.38	1.28	4.22	0.24	1.73	81.08	-14.6	0.2	-0.34

TABLE A-3. (Continued)

PILOT J

RUN	CONFIGURATION PITCH	ROLL	HQR	PITCH LOOP ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	ROLL LOOP ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA
18N573	11	---	2.0	0.4	0.13	3.65	33.09	-27.8	0.17	1.3							
18N574	11	---		0.4	0.11	3.03	42.53	-24.8	0.23	0.21							
18N575	4	---	2.0	0.54	0.07	3.32	34.78	-15	0.3	-0.22							
18N576	4	---		0.54	0.07	3.65	28.52	-20.8	0.32	-0.37							
18N577	8	---	3.0	0.69	0.08	3.07	31.29	-8.1	0.34	-0.26							
18N578	8	---		0.71	0.08	2.83	38.76	-10	0.33	-0.31							
18N579	5	---	5.0	0.91	0.05	1.5	62.06	-7.3	0.3	-0.01							
18N580	5	---		0.92	0.05	1.3	73.58	-13.4	0.42	-0.34							
18N581	12	---	4.0	0.74	0.28	1.97	15.92	-32.6	0.35	0.87							
18N582	12	---		0.74	0.25	2.07	5.59	-30.9	0.44	0.8							
18N583	4	---	4.0	0.55	0.07	2.76	45.23	-16.4	0.32	-0.43							
18N584	4	---		0.55	0.07	3.23	37.4	-14.1	0.3	-0.29							
18N585	---	F	2.0								3.41	0.24	2.45	27.8	-22.9	0.47	-0.19
18N586	---	F									3.66	0.26	2.43	28.56	-24	0.46	-0.17
18N587	---	H	4.0								4.31	0.45	2.06	38.08	-22.7	0.49	-0.32
18N588	---	H									4.49	0.31	1.59	47.56	-21.3	0.54	-0.26
18N589	---	G	5.0								7.06	1.25	1.84	8.84	-25.9	0.55	0.57
18N590	---	G									5.64	1.12	1.92	8.01	-26.2	0.59	0.38
18N591	---	F	2.0								3.6	0.25	2.33	32.33	-23.2	0.44	-0.13
18N592	---	F									3.57	0.24	2.31	31.04	-22.8	0.45	-0.08
18N593	11	F	3.0	0.5	0.1	2.28	58.29	-20.3	0.25	-0.17	5.07	0.31	2.19	24.39	-19	0.57	-0.31
18N594	11	F		0.55	0.11	2.48	52.64	-18.7	0.22	0.07	4.83	0.32	2.31	29.81	-20.8	0.55	-0.59
18N595	4	F	3.0	0.73	0.08	3.11	29.53	-12.7	0.34	-0.16	4.57	0.22	1.9	34.19	-24.5	0.53	-0.18
18N596	4	F		0.68	0.08	3.84	22.78	-16.9	0.34	-0.6	4.64	0.22	1.74	35.23	-22.7	0.6	-0.29
18N597	8	H	6.0	0.85	0.09	2.53	42.63	-10.4	0.35	-0.35	5.62	0.33	1.62	33.46	-22.7	0.67	-0.28
18N598	8	H		0.8	0.08	2.69	43.44	-12.4	0.35	-0.54	5.62	0.32	1.78	8.31	-23.4	0.8	-0.16
18N599	5	G	7.5	1.23	0.04	0.04	78.75	-4.1	-0.54	-0.01	11.7	0.79	1.03	33.84	-33	0.95	-0.02
18N600	5	G		1.09	0.04	0.32	86.56	-21.2	-0.83	0.1	8.43	0.63	0.92	51.74	-24.9	0.84	-0.11
18N601	5	F	6.0	1.01	0.05	1.15	88.8	-9.4	-0.05	0.08	5.02	0.18	1.27	54.16	-24.6	0.54	-0.1
18N602	5	F		0.98	0.04	0.78	86.24	-8	0.25	-0.1	5.89	0.18	1.28	44.72	-22.5	0.66	-0.1
18N603	8	F	3.0	0.73	0.07	1.93	52.5	-12.4	0.36	-0.24	4.85	0.25	1.87	35.4	-21.4	0.59	-0.39
18N604	8	F		0.7	0.07	1.95	55.98	-12.6	0.33	-0.24	4.48	0.2	1.63	45.64	-21.8	0.57	-0.32
18N605	12	F	7.0	1.89	0.38	1.41	24.8	-32.2	0.23	1.09	5.64	0.38	1.25	92.78	-10.1	0.59	-0.98
18N606	12	F		1.4	0.36	1.64	16.42	-29.4	0.37	0.92	4.75	0.4	2.2	33.59	-18.6	0.47	-0.18

TABLE A-3. (Concluded)

PILOT M

RUN	CONFIGURATION PITCH	CONFIGURATION ROLL	HQR	PITCH LOOP ESIG	PITCH LOOP CSIG	PITCH LOOP WC	PITCH LOOP PML	PITCH LOOP SLOPE	PITCH LOOP TE	PITCH LOOP ALPHA	ROLL LOOP ESIG	ROLL LOOP CSIG	ROLL LOOP WC	ROLL LOOP PML	ROLL LOOP SLOPE	ROLL LOOP TE	ROLL LOOP ALPHA
20N608	11	---	2.0	0.44	0.15	2.62	52.21	-20.9	0.23	-0.01							
20N609	11	---		0.45	0.15	2.58	49.05	-21.6	0.25	0.03							
20N610	4	---	3.0	0.6	0.17	2.69	40.51	-13.6	0.36	-0.47							
20N611	4	---		0.6	0.16	2.65	43.6	-10.8	0.35	-0.49							
20N612	12	---	4.0	0.78	0.35	2.03	17.33	-27.5	0.35	0.83							
20N613	12	---		0.84	0.32	1.91	13.45	-27	0.41	0.78							
20N614	8	---	5.0	0.73	0.13	2.02	58.03	-7.3	0.37	-0.53							
20N615	8	---		0.66	0.1	1.45	81.53	-8.6	0.38	-0.63							
20N616	13	---	7.0	1.43	0.56	2.98	20.94	-14.6	0.23	1.32							
20N617	13	---		1.26	0.56	3.86	17.88	-19.9	0.17	2.28							
20N618	5	---	6.0	0.92	0.2	1.46	62.37	-14.8	0.33	-0.06							
20N619	5	---		0.78	0.17	1.27	70	-22.2	0.34	-0.1							
20N620	8	---	3.0	0.72	0.21	1.41	76.72	-8.6	0.42	-0.54							
20N621	8	---		0.73	0.21	1.3	80.01	-7.5	0.41	-0.46							
20N622	---	J	2.0								2.8	0.24	2.71	35.46	-23.9	0.19	1.09
20N623	---	J									2.7	0.22	2.84	46.52	-27.2	0.18	0.65
20N624	---	F	2.0								3.5	0.4	2.69	24.03	-30.8	0.41	0.07
20N625	---	F									3.63	0.38	2.14	38.98	-23.1	0.44	-0.21
20N626	---	H	4.0								4.63	0.72	2.22	29.76	-16.3	0.47	-0.05
20N627	---	H									4.61	0.65	1.99	33.51	-17.6	0.51	-0.15
20N628	---	G	6.0								5.7	1.12	1.82	13.1	-23.7	0.53	0.52
20N629	---	G									5.58	1.04	1.71	22.89	-21.2	0.57	0.2
20N630	---	H	4.0								4.44	0.53	1.9	38.6	-17.8	0.5	-0.22
20N631	---	H									4.27	0.61	2.27	28.24	-18	0.49	-0.16
20N632	11	J	2.0	0.55	0.19	2.49	53.42	-19.6	0.19	0.22	3.28	0.33	2.36	60.36	-20.6	0.21	0
20N633	11	J		0.51	0.18	2.65	47.32	-21.7	0.24	0.14	2.99	0.31	3.13	39.61	-27.8	0.21	0.49
20N634	4	F	4.0	0.83	0.26	2.5	53.74	-9.1	0.32	-0.55	4.86	0.56	2.31	22.97	-22.9	0.53	-0.22
20N635	4	F		0.71	0.22	2.34	61.26	-12.4	0.27	-0.41	4.57	0.52	2.13	30.61	-19.8	0.46	0.02
20N636	5	F	7.0	1.14	0.24	0.58	83.6	-27	0.59	-0.13	4.79	0.55	2.44	23.67	-16.4	0.45	0.08
20N637	5	F		1.23	0.28	1.01	94.96	-19.4	-0.22	0.15	5.14	0.57	2.35	23.52	-20.7	0.5	-0.1
20N638	12	H	7.0	1.2	0.57	1.93	11.15	-31.3	0.33	1.11	5.8	0.75	2.14	22.55	-18	0.47	0.23
20N639	12	H		0.98	0.48	2.17	10.04	-28.2	0.35	1.02	5.37	0.63	1.63	36.04	-27.1	0.5	0.09
20N640	8	H	5.0	0.8	0.3	1.37	85.07	-10.1	0.35	-0.55	4.83	0.58	1.77	34.09	-21.5	0.51	0
20N641	8	H		0.8	0.27	1.6	82.33	-9.1	0.37	-0.76	5.2	0.61	1.93	30.35	-15.9	0.49	0.07
20N642	12	J	4.0	0.91	0.49	2.34	6.54	-27.9	0.33	1.21	3.48	0.41	1.93	72.61	-19.3	0.21	-0.25
20N643	12	J		0.81	0.48	2.59	5.24	-31.5	0.37	0.99	3.52	0.44	2.55	46.7	-16	0.31	-0.08
20N644	5	G	8.0	1.33	0.32	0.17	70.31	-24.7	-0.69	0.08	9.74	1.16	1.29	25.71	-22.5	0.62	0.38
20N645	5	G		1.11	0.29	0.4	83.66	-24.7	-0.27	0.08	6.98	1.08	1.52	20.2	-27	0.59	0.37
20N646	13	H	8.0	1.89	0.74	3.05	23.41	-13.8	0.23	1.15	6.99	0.99	2	21.18	-19.2	0.59	-0.09
20N647	13	H		1.77	0.68	2.95	17.54	-12.2	0.27	1.06	5.26	0.78	1.97	14.06	-23.5	0.62	0.06
20N648	12	F	5.0	0.97	0.62	2.66	10.49	-28.3	0.31	1.11	4.21	0.6	3.05	21.17	-17.9	0.41	-0.41
20N649	12	F		0.99	0.56	2.44	2.91	-27	0.33	1.34	4.15	0.57	2.3	35.95	-18.6	0.41	-0.09

TABLE A-6. OPEN-LOOP DESCRIBING FUNCTION DATA

RUN	FREQUENCY (RAD/SEC) GAIN (dB) PHASE (DEG) OF YPYC (PITCH)									
	0.26		0.60		1.30		3.60		7.70	
200	24.82	-99.0	13.16	-107.8	7.55	-118.1	-3.44	-151.1	-12.19	-183.6
203	20.98	-114.8	13.63	-118.3	6.29	-121.5	-5.06	-145.8	-12.72	-179.9
204	22.14	-103.6	15.60	-107.6	7.21	-119.8	-3.83	-152.5	-11.59	-176.1
207	17.07	-108.9	11.13	-93.7	3.97	-109.1	-5.02	-141.9	-11.43	-178.9
208	15.45	-97.7	9.93	-96.0	3.23	-101.0	-7.08	-147.0	-13.67	-181.7
212	18.51	-110.7	8.93	-100.9	4.18	-98.0	-3.92	-136.3	-9.71	-179.4
213	18.73	-90.6	11.66	-89.9	6.10	-99.9	-2.52	-143.2	-11.04	-175.4
214	8.35	74.2	14.75	-162.9	10.11	-145.6	-1.48	-171.7	-6.67	-222.2
215	19.29	-19.6	18.68	-157.6	9.15	-157.2	-3.29	-181.0	-10.17	-242.2
216	15.18	-195.4	13.60	-134.2	6.96	-159.3	-4.41	-185.7	-11.47	-230.6
217	26.38	-92.3	30.77	-221.7	7.42	-172.5	-7.36	-187.0	-12.48	-234.1
218	11.28	-246.9	9.96	-184.3	10.55	-165.9	-3.99	-176.4	-11.18	-235.7
220	18.41	-7.3	26.17	-131.6	7.34	-164.3	-4.73	-187.6	-10.60	-237.3
221	16.73	-88.0	15.96	-162.9	8.13	-162.0	-3.17	-177.4	-10.56	-231.7
222	7.37	-166.3	6.00	-167.4	6.87	-150.0	2.24	-169.4	-5.73	-183.4
223	8.30	-182.3	8.26	-161.9	8.32	-159.2	2.38	-165.9	-4.23	-177.9
225	9.05	-167.3	5.04	-175.6	3.41	-154.7	-0.59	-152.1	-3.38	-180.0
226	7.33	-182.0	6.38	-165.0	5.11	-162.4	1.96	-167.2	-4.59	-167.2

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (PITCH)

RUN	0.20		0.50		0.90		1.40		2.40		4.20		9.00	
17FEB89.AB	38.54	-34.1	18.72	-109.1	11.04	-117.3	6.85	-133.3	.17	-134.1	-3.67	-150.9	-4.97	-197.7
17FEB89.AC	35.13	-114.9	19.80	-111.9	11.62	-123.0	6.83	-132.0	.93	-132.7	-2.87	-148.8	-5.65	-194.0
17FEB89.AD	24.92	-104.9	15.67	-104.1	10.92	-109.3	6.73	-119.2	3.79	-118.9	-.77	-143.9	-3.42	-227.3
17FEB89.AE	23.66	-113.8	13.58	-102.3	10.64	-111.5	6.04	-118.5	1.73	-110.7	-1.72	-144.9	-2.07	-219.5
17FEB89.AF	21.01	-106.7	10.76	-99.1	6.45	-109.7	1.77	-127.7	-2.34	-127.3	-2.24	-159.5	-.97	61.0
17FEB89.AG	18.59	-105.6	12.54	-104.3	8.26	-119.7	2.63	-128.7	-1.54	-131.4	-2.73	-158.1	.84	56.9
17FEB89.AH	25.05	-87.6	14.39	-93.7	9.77	-113.8	4.84	-121.0	-.99	-124.4	-3.07	-140.8	-2.72	-228.4
17FEB89.AI	21.65	-99.0	15.33	-91.6	10.63	-112.6	6.65	-121.0	1.48	-136.0	-1.98	-140.0	-2.35	-227.2
17FEB89.AJ	11.46	-102.5	4.84	-96.3	.49	-112.4	-.69	-116.8	-5.65	-134.9	-6.33	-158.2	-9.73	-26.2
17FEB89.AK	17.77	-97.8	5.73	-99.2	2.70	-112.5	-2.43	-113.6	-6.78	-131.4	-7.03	-159.7	-10.36	-9.7
17FEB89.AL	15.66	-86.5	8.08	-103.7	1.92	-104.2	-.64	-105.6	-4.37	-127.9	-7.89	-174.8	-9.90	-21.8
17FEB89.AU	24.52	-142.3	14.38	-129.7	6.25	-131.3	.42	-119.9	-2.56	-135.6	-7.79	-147.2	-8.71	-196.9
17FEB89.AV	25.43	-109.1	14.52	-121.6	6.24	-122.7	2.15	-124.9	-4.11	-128.7	-6.48	-143.5	-7.01	-201.2
17FEB89.AW	19.00	-91.4	16.61	-133.0	7.25	-123.8	3.24	-123.8	-1.17	-123.9	-6.29	-144.4	-6.70	-197.0
17FEB89.AX	16.06	-108.4	11.06	-107.8	4.55	-109.8	1.87	-109.4	-4.47	-122.7	-3.11	-154.4	-.33	35.5
17FEB89.AY	12.15	-98.8	9.97	-112.7	2.77	-114.9	-.22	-117.4	-4.33	-127.3	-2.78	-146.2	.83	55.2
17FEB89.AZ	15.12	-111.3	7.45	-106.0	.58	-108.7	-2.12	-120.2	-6.47	-127.9	-4.73	-152.5	-2.75	20.1
17FEB89.BA	23.93	-154.9	12.91	-103.4	4.86	-107.0	1.64	-108.2	-2.59	-113.2	-3.47	-132.8	-2.47	-232.6
17FEB89.BB	30.25	-4.7	10.08	-86.0	4.75	-100.5	1.25	-101.9	-4.08	-104.8	-3.81	-131.6	-2.25	-243.9
17FEB89.BC	18.54	-114.5	8.24	-106.9	1.34	-98.1	-2.01	-102.0	-4.90	-97.0	-4.12	-122.8	-5.25	-235.1
17FEB89.BD	9.00	-100.3	7.42	-103.4	3.57	-93.3	-1.92	-83.1	-.42	-92.4	-3.59	-128.6	-3.17	-229.3
17FEB89.BE	28.05	-89.2	6.66	-97.1	2.48	-110.8	-1.67	-110.0	-5.10	-103.4	-3.48	-129.7	-3.31	-233.3
17FEB89.BF	[illegible]	-121.2	7.77	-94.5	3.90	-100.9	1.68	-102.8	-2.48	-102.7	-2.91	-125.4	-2.03	-226.8

TABLE A-4. (CONTINUED)

RUN	FREQUENCY (RAD/SEC)									
	GAIN (dB) PHASE (DEG) OF YPYC (ROLL)									
	0.43		0.77		1.20		2.60		6.0	
201	20.24	-110.6	12.43	-106.5	8.12	-117.6	-1.05	-138.0	-10.93	-154.5
202	17.07	-124.1	12.39	-111.2	9.18	-116.5	-0.35	-137.7	-11.03	-154.3
203	18.13	-81.5	15.89	-113.5	12.81	-114.2	2.17	-150.9	-6.07	-176.3
204	20.69	-116.1	14.07	-94.1	10.87	-113.4	1.77	-148.2	-7.24	-180.3
205	15.65	-105.8	15.29	-127.5	10.26	-129.1	0.76	-160.4	-9.70	-211.8
206	19.63	-96.9	14.35	-115.0	9.17	-123.4	0.61	-158.8	-9.43	-212.7
207	13.34	-88.6	13.08	-108.6	8.11	-124.5	1.31	-164.2	-7.75	-234.7
208	12.85	-91.1	12.31	-112.6	6.95	-115.0	-0.28	-163.3	-8.17	-225.5
209	14.72	-85.7	11.96	-109.0	9.09	-125.9	0.19	-162.4	-9.97	-219.0
210	13.94	-123.5	13.02	-139.0	7.43	-149.2	-3.66	-189.9	-13.00	-239.8
211	21.90	-98.5	13.00	-116.8	7.75	-147.3	-3.11	-192.9	-15.05	-234.3
212	14.55	-71.9	8.82	-115.4	5.58	-139.2	-4.16	-175.1	-15.89	-260.0
213	18.29	-129.8	11.11	-147.2	6.42	-127.3	-4.16	-193.0	-14.41	-259.1
215	-1.54	-194.4	4.62	-164.9	4.47	-140.2	4.47	-140.2	4.47	-140.2
	[illegible].80	-195.6	-5.04	-204.6	5.65	-155.5	5.65	-155.5	5.65	-155.5
	[illegible].75	-86.6	8.26	-119.7	6.23	-129.9	-3.20	-177.0	-11.25	-260.5
218	.21	-121.2	7.22	-107.3	5.97	-132.2	-4.24	-177.1	-12.82	-265.2
219	16.38	-101.3	10.53	-86.8	7.87	-102.7	0.21	-125.1	-9.10	-152.3
220	13.24	-101.4	7.96	-80.6	4.34	-96.1	-3.89	-111.8	-7.45	-164.6
221	13.43	-117.7	8.10	-96.2	4.77	-103.3	-3.48	-128.1	-8.02	-164.5
224	25.77	-34.9	12.16	-126.8	7.90	-148.7	-2.85	-187.0	-12.76	-238.2
225	7.80	-103.8	9.62	-141.3	4.25	-141.2	-6.50	-199.5	-16.24	89.1
226	24.84	-126.5	9.58	-122.3	4.57	-146.6	-5.69	-198.6	-16.99	-268.9

TABLE A-4. (CONTINUED)

RUN	FREQUENCY (RAD/SEC) GAIN (dB) PHASE (DEG) OF YPYC (PITCH)									
	0.26		0.60		1.30		3.60		7.7	
238	21.81	-115.7	16.90	-102.8	10.30	-113.5	-0.05	-148.3	-10.55	-191.6
239	20.42	-89.2	15.53	-96.5	10.01	-108.8	0.18	-146.3	-9.86	-199.5
240	19.31	-79.4	13.50	-81.5	7.58	-104.9	0.95	-153.1	-7.01	-226.8
241	19.68	-81.5	10.13	-86.2	7.29	-99.6	0.34	-153.5	-8.07	-222.0
242	10.55	-87.7	1.37	-80.4	-2.54	-86.9	-4.29	-136.7	-7.15	71.0
243	5.36	-95.0	2.33	-92.6	-2.44	-86.8	-7.03	-132.0	-6.10	69.1
244	16.27	-92.8	5.12	-83.1	3.36	-95.8	-2.76	-166.1	-5.32	-263.9
245	12.30	-99.0	9.31	-78.3	4.92	-90.7	-1.43	-156.8	-1.34	-265.7
246	16.38	-99.6	8.76	-75.5	3.41	-97.9	-1.52	-152.8	-0.34	-256.4
247	9.25	-82.9	2.85	-85.0	-0.41	-86.8	-3.42	-108.7	-8.37	-226.0
248	11.29	-94.9	3.94	-78.9	-0.13	-88.7	-4.13	-114.3	-9.33	-224.5
249	32.30	-98.7	14.43	-171.8	7.35	-165.6	-7.29	-183.7	-13.20	-210.9
250	22.10	-143.3	15.03	-185.9	7.97	-166.6	-6.47	-189.0	-12.41	-222.9
251	14.21	-87.3	7.50	-85.1	5.70	-88.7	-0.24	-146.8	-7.08	-221.3
252	16.69	-85.1	7.89	-78.8	5.04	-98.8	-0.14	-150.1	-6.47	-230.6
253	14.47	-108.0	8.46	-91.0	4.87	-93.8	-1.18	-146.0	-5.39	-202.3
254	15.11	-96.4	9.25	-81.1	4.21	-96.2	-2.51	-143.2	-5.53	-203.6
255	15.43	-94.9	9.68	-90.1	5.42	-93.0	-1.60	-145.0	-6.07	-219.7
272	16.09	-151.6	16.57	-156.3	16.32	-98.1	16.08	-151.6	16.32	-98.1
273	29.83	-249.1	16.79	-113.0	9.56	-115.9	-0.24	-142.2	-9.15	-179.6
274	21.94	-107.5	14.83	-123.8	8.40	-114.9	-1.06	-139.0	-9.88	-172.1
275	18.74	-127.0	12.56	-106.9	6.40	-107.4	-2.07	-137.4	-10.59	-182.2
276	15.48	-88.7	5.40	-94.7	2.01	-87.1	-1.61	-141.4	-7.25	-223.5
277	20.30	-101.8	7.56	-81.2	3.20	-84.7	-0.20	-143.8	-6.20	-230.4
278	15.24	-62.5	7.03	-93.1	4.01	-88.5	0.43	-142.3	-5.78	-221.4
279	17.20	-112.9	12.55	-106.2	9.69	-110.0	-2.08	-142.1	-8.52	-175.9

TABLE A-4. (CONTINUED)

RUN	FREQUENCY (RAD/SEC) GAIN (dB) PHASE (DEG) OF YPYC (ROLL)									
	0.43		0.77		1.20		2.60		6.0	
256	18.85	-95.1	15.51	-97.6	9.64	-127.1	2.22	-149.5	-10.96	-156.8
257	19.37	-100.4	15.79	-121.0	11.06	-128.2	2.45	-150.4	-10.11	-169.1
258	13.63	-96.4	12.13	-101.7	6.80	-121.0	0.38	-155.9	-10.06	-219.5
259	14.51	-101.4	9.81	-108.2	6.49	-114.1	0.92	-154.8	-9.49	-220.9
260	13.07	-108.4	11.68	-111.7	6.60	-131.7	-3.02	-165.7	-13.72	-221.7
261	20.47	-104.5	13.39	-136.5	7.78	-141.6	-0.12	-164.3	-10.71	-227.7
262	17.46	-129.3	7.67	-109.3	4.71	-128.9	-1.53	-157.9	-7.70	-256.0
263	8.78	-69.3	6.39	-104.6	3.19	-124.5	-2.52	-160.8	-12.43	-253.3
264	10.35	-107.6	5.63	-108.1	3.68	-112.6	-0.96	-154.1	-8.69	-231.6
265	9.31	-99.4	6.49	-94.9	4.83	-109.8	-1.95	-156.3	-10.96	-231.6
266	10.57	-99.7	7.16	-96.4	4.23	-113.6	-0.14	-152.3	-8.57	-240.0
267	10.91	-123.9	7.18	-111.6	3.61	-130.8	-4.13	-161.8	-14.52	-218.3
268	16.08	-113.5	10.24	-113.2	6.41	-135.5	-2.61	-164.5	-11.85	-227.9
271	16.99	-130.1	8.09	-130.2	5.74	-135.5	-3.18	-178.4	-10.67	-252.6
272	17.45	-132.9	10.96	-123.3	5.77	-132.3	-2.07	-166.0	-10.16	-248.1
273	15.34	-75.7	10.90	-103.0	7.12	-111.1	2.47	-134.6	-6.64	-178.8
274	18.20	-124.0	11.66	-113.3	9.14	-115.4	1.63	-146.5	-6.70	-175.6
275	18.42	-104.9	13.14	-96.7	7.57	-111.0	0.62	-131.2	-8.02	-170.8
276	12.14	-112.8	8.30	-94.9	6.55	-122.5	0.19	-163.1	-7.90	-232.0
277	14.80	-91.9	11.54	-105.6	6.60	-121.2	-0.19	-162.7	-8.53	-226.3
278	15.16	-89.9	10.37	-109.0	7.04	-124.2	-0.39	-158.2	-9.24	-226.7
279	15.90	-91.4	11.40	-112.4	6.99	-119.2	-0.69	-134.2	-6.73	-166.3

TABLE A-4. (CONTINUED)

RUN	FREQUENCY (RAD/SEC)									
	GAIN (dB) PHASE (DEG) OF YPYC (PITCH)									
	0.26		0.60		1.30		3.60		7.70	
280	29.59	-86.7	14.17	-103.4	7.16	-108.4	0.14	-147.9	-9.13	-200.1
281	12.44	-104.3	6.51	-93.8	2.08	-92.1	-2.74	-153.2	-11.22	-238.3
282	10.05	-79.8	4.91	-79.7	1.47	-93.2	-1.69	-160.3	-2.97	67.4
283	5.10	-98.5	0.27	-86.3	-3.94	-90.7	-3.76	-140.6	-8.18	32.3
284	21.95	67.0	17.72	-155.9	7.07	-164.6	-5.48	-188.9	-12.21	-232.0
285	5.77	-91.0	0.61	-92.0	-3.19	-100.0	-5.59	-170.0	-12.75	35.5
286	9.31	-103.6	1.37	-81.5	-1.53	-83.3	-3.08	-139.8	-11.10	-261.7
287	11.42	-85.4	5.39	-81.1	1.51	-93.2	-4.39	-157.4	-11.33	-233.8
288	8.86	-102.1	3.00	-80.2	-0.18	-84.4	-3.15	-153.4	-3.80	61.9
295	19.59	-157.1	14.03	-108.1	7.64	-104.1	-0.25	-143.1	-7.63	-180.2
296	9.16	-101.1	6.20	-93.9	2.60	-77.0	-0.13	-128.8	-6.17	-207.9
297	12.73	-111.2	5.25	-92.7	0.97	-80.0	-3.38	-135.3	-5.28	-210.3
298	10.70	-95.7	4.60	-76.3	1.49	-92.6	-2.60	-143.1	-9.30	-212.4
299	8.49	-87.1	2.34	-76.8	-1.19	-88.1	-4.03	-159.0	-6.26	-269.8
300	5.14	-90.4	-1.77	-80.2	-6.48	-81.6	-6.28	-144.2	-6.78	42.4
301	8.82	-91.3	3.47	-70.6	-1.31	-83.0	-0.39	-139.2	-1.66	81.1
302	8.22	-106.9	2.31	-84.6	-2.29	-87.1	-1.97	-151.7	-3.44	78.6
303	12.62	-107.1	0.85	-98.1	-1.90	-76.5	-3.63	-139.2	-6.34	-229.5
304	10.53	-114.6	3.30	-76.8	0.26	-90.0	-2.55	-136.6	-8.59	-216.9
305	5.72	-87.7	3.30	-83.8	-2.15	-73.8	-2.30	-143.2	-4.20	78.6
306	18.31	-109.5	10.10	-109.4	4.92	-109.6	-6.42	-142.2	-9.25	-177.3
307	9.54	-95.5	0.65	-86.3	-1.99	-80.9	-4.24	-154.6	-5.68	66.3
308	15.28	-77.9	6.39	-90.8	2.93	-83.3	-2.01	-133.2	-7.43	-211.5
309	26.92	-107.0	13.79	-100.9	7.98	-123.7	-2.90	-153.4	-12.13	-186.3
310	26.39	-104.5	16.03	-102.1	10.18	-118.1	0.08	-148.0	-9.47	-184.7
311	19.32	-111.5	12.16	-95.4	7.24	-96.5	1.02	-148.3	-7.57	-216.0
312	20.07	-99.7	11.45	-93.6	5.98	-101.1	0.91	-147.9	-7.74	-217.3
313	12.40	-107.3	7.01	-89.6	4.31	-90.4	-0.80	-153.7	-0.92	-259.4
314	15.05	-106.4	8.15	-100.3	3.14	-95.3	-0.83	-156.7	-1.35	-259.5
315	15.55	-123.1	5.94	-93.8	1.51	-89.5	-1.08	-143.8	-1.86	-264.3
316	12.19	-106.5	5.25	-84.2	1.46	-86.5	-1.16	-142.4	-1.30	-270.0
317	12.86	-110.0	3.11	-91.9	-1.67	-98.7	-5.45	-130.8	-3.14	73.8
318	7.24	-94.9	3.14	-88.9	-1.48	-98.8	-5.01	-124.6	-5.38	71.5
319	13.09	-124.3	5.02	-107.5	1.18	-110.9	-4.91	-138.5	2.06	-264.3
320	13.82	-100.3	4.23	-109.8	-1.08	-104.9	-5.96	-136.0	0.27	-254.8
321	16.04	-93.2	7.21	-103.6	1.20	-115.3	-3.67	-168.0	-4.17	-247.9
322	18.47	-80.9	8.87	-104.3	2.55	-106.8	-2.64	-151.8	-1.99	-248.9
323	10.33	-199.0	7.47	-139.3	2.45	-148.6	-9.44	-180.8	-17.25	-214.6
324	24.89	-137.7	16.98	-174.6	4.25	-170.1	-11.49	-201.2	-16.90	-252.3
325	13.29	-132.1	9.65	-90.2	4.07	-143.3	-9.01	-230.1	-18.26	44.3
326	16.22	-62.5	7.06	-113.9	3.90	-145.1	-9.74	-235.0	-18.68	42.9
327	17.54	-104.2	11.39	-89.6	5.68	-97.5	0.05	-146.4	-7.82	-216.1
328	15.81	-106.6	10.35	-90.3	5.43	-95.2	-0.57	-147.2	-9.37	-213.9
329	14.45	-36.5	15.53	-146.8	7.76	-159.7	-5.64	-190.6	-14.13	-230.8
330	8.96	-30.5	18.19	-179.6	7.73	-162.4	-4.74	-191.6	-12.91	-239.4
331	14.84	-88.9	8.84	-93.3	3.87	-90.1	0.11	-149.0	-7.38	-227.3
332	18.16	-125.9	9.18	-87.1	4.63	-98.0	-0.13	-149.2	-6.46	-225.2
347	15.37	-100.9	1[illegible].34	-112.9	4.71	-115.3	-4.67	-141.8	-12.88	-180.1

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (ROLL)

RUN	0.30		0.40		0.70		1.80		3.00		4.00		7.00	
21FEB89.BH	16.75	-131.0	18.06	-122.2	12.44	-126.3	1.46	-145.2	-3.24	-170.4	-5.84	-191.4	-9.06	88.0
21FEB89.BI	14.38	-61.9	29.82	-212.6	15.49	-167.3	1.13	-145.5	-2.67	-166.4	-5.33	-193.2	-8.68	-265.1
21FEB89.BJ	11.92	-91.3	13.05	-85.1	12.99	-132.0	1.45	-134.8	-5.29	-166.3	-5.73	-196.4	-10.62	84.9
21FEB89.BK	26.28	-203.9	10.60	-50.0	8.27	-142.2	-2.21	-148.6	-11.60	-248.9	-8.13	-239.8	-17.85	30.8
21FEB89.BL	14.12	-142.8	10.72	-70.0	10.70	-152.5	-.11	-157.2	-5.81	-206.3	-10.08	35.6	-16.45	30.9
21FEB89.BM	10.76	-90.7	10.31	-70.4	5.74	-106.6	-.29	-126.9	-3.34	-144.3	-9.42	-171.2	-6.86	-207.5
21FEB89.BN	12.23	-97.4	16.40	-79.4	8.05	-108.2	-.62	-134.0	-7.20	-162.9	-16.03	-143.7	-7.51	-214.0
21FEB89.BO	8.67	-71.3	5.56	-70.6	6.18	-117.0	-4.96	-141.6	-3.80	-162.0	-3.11	-169.5	-7.95	78.9
21FEB89.BP	10.57	-55.3	12.94	-75.4	9.60	-125.6	-.67	-133.8	-7.85	-176.8	-4.64	-177.9	-12.07	32.3
21FEB89.BQ	15.72	-79.4	15.61	-76.7	9.97	-105.7	-.19	-137.0	-4.44	-155.2	-5.44	-187.6	-10.60	68.1
21FEB89.BR	12.22	-62.1	13.89	-73.9	8.33	-114.4	-.80	-140.6	-4.61	-168.3	-7.34	-200.0	-10.78	62.1
21FEB89.BS	8.06	-150.1	3.24	-8.8	10.34	-119.0	-2.33	-164.5	-12.93	-209.4	-5.69	-240.4	-16.25	-10.9
21FEB89.BT	18.51	82.7	4.99	-65.4	2.29	-91.9	-1.64	-164.5	-4.01	-213.8	-9.21	77.9	-23.74	17.3
21FEB89.BU	23.85	-77.1	27.08	-70.4	7.70	-112.8	-2.49	-132.8	-4.31	-150.0	-11.36	-166.7	-8.07	41.7
21FEB89.BV	12.95	-71.3	8.99	-61.3	3.81	-109.8	-.94	-134.0	-6.87	-161.4	-3.72	-195.8	-12.85	50.1
21FEB89.BW	19.98	-2.7	17.48	-54.6	6.75	-88.8	-1.48	-127.7	-5.14	-140.2	-8.72	-153.0	-6.08	-205.3
21FEB89.BX	15.78	-98.8	13.77	-78.5	6.40	-96.8	-1.16	-134.2	-6.05	-136.7	-6.04	-166.3	-7.05	-216.7
21FEB89.BZ	8.07	-48.7	14.94	-114.5	5.14	-102.2	-3.36	-141.7	-10.05	-154.7	-6.46	-216.5	-20.14	57.9

TABLE A-4. (CONTINUED)

RUN	FREQUENCY (RAD/SEC) GAIN (dB) PHASE (DEG) OF YPYC (PITCH)									
	0.26		0.60		1.30		3.60		7.70	
348	19.70	-100.7	13.42	-106.5	6.77	-116.3	-3.44	-145.3	-11.68	-178.7
349	12.41	-90.8	7.79	-79.4	4.07	-92.8	-1.17	-158.0	-4.52	-230.2
350	17.28	-91.8	9.57	-79.9	5.12	-93.6	0.92	-148.0	-3.37	-231.3
351	10.61	-135.0	4.05	-97.9	0.91	-71.5	-4.20	-152.0	-4.96	-238.9
352	13.41	-139.8	4.12	-99.4	0.82	-86.2	-1.76	-142.8	-5.70	-230.4
353	11.65	-76.0	2.67	-98.8	-2.03	-91.8	-8.84	-126.7	-14.13	-154.0
354	13.13	-101.5	6.16	-80.3	1.10	-86.1	-8.47	-132.9	-11.68	-162.6
355	15.98	-134.3	5.86	-106.4	2.33	-97.7	-0.99	-158.7	-2.80	79.5
356	12.38	-96.5	7.49	-95.1	4.46	-90.5	-0.94	-157.3	-2.63	-269.7
357	6.42	-95.3	3.74	-86.2	1.22	-75.4	-1.19	-145.2	-1.21	-268.4
358	8.79	-96.1	5.05	-97.6	0.87	-79.8	-0.42	-153.9	-2.39	88.1
359	12.82	-89.2	7.27	-86.0	3.41	-86.4	0.38	-144.9	-2.96	-231.4
360	16.02	-116.5	7.76	-90.1	3.69	-90.6	-0.07	-132.9	-3.31	-224.5
361	13.07	-5.1	14.25	-181.6	3.52	-153.1	-8.30	-197.0	-12.88	-2[illegible]3.1
362	13.12	-198.3	19.48	-180.1	5.67	-157.9	-5.69	-172.6	-12.05	-232.1
363	10.70	-13.2	18.27	-212.6	6.49	-166.8	-6.74	-175.1	-12.10	-220.6
364	18.19	-130.4	18.36	-181.4	7.32	-168.6	-6.23	-196.4	-12.56	-220.7
365	5.60	-96.2	2.17	-67.8	-1.61	-62.4	0.05	-126.0	-1.52	-264.1
366	15.96	-99.1	4.02	-83.1	-0.55	-84.9	-2.36	-147.5	-1.16	-267.2
367	15.84	-96.9	6.93	-95.7	2.72	-88.2	-1.44	-136.9	-7.10	-209.5
368	15.85	-66.1	8.25	-94.5	3.61	-91.6	-1.21	-135.6	-6.90	-208.3

TABLE A-4. (CONTINUED)

RUN	FREQUENCY (RAD/SEC) GAIN (dB) PHASE (DEG) OF YPYC (ROLL)									
	0.43		0.77		1.20		2.60		6.0	
289	9.96	-74.2	8.88	-94.3	5.06	-98.5	-0.74	-132.8	-7.96	-157.1
290	17.77	-65.2	10.72	-97.7	6.17	-126.4	-0.76	-154.2	-9.59	-220.6
291	8.66	-77.3	8.92	-109.9	3.69	-119.0	-3.06	-155.9	-12.30	-221.3
292	15.39	-112.2	8.91	-97.5	6.00	-133.7	-2.89	-180.4	-9.06	-269.7
293	10.44	-87.3	7.70	-111.7	4.42	-122.9	-1.56	-163.9	-7.70	-257.3
294	13.67	-82.4	8.21	-154.3	3.69	-155.7	-4.97	-192.9	-8.45	70.4
296	17.46	-138.7	8.93	-140.7	10.46	-108.3	2.29	-165.6	-4.12	-216.7
297	10.25	-133.7	9.91	-117.8	8.76	-116.0	-1.98	-151.0	-2.37	-250.8
298	16.11	-39.2	11.20	-91.2	4.15	-122.6	-3.03	-166.1	-5.81	-261.8
299	11.98	-111.1	7.55	-115.1	4.18	-112.4	-1.26	-160.5	-7.20	-254.8
300	8.59	-143.3	10.06	-136.5	4.83	-151.9	-3.70	-205.0	-9.93	28.0
301	13.94	-111.6	8.73	-119.4	4.47	-145.9	-5.19	-180.4	-3.93	39.4
302	9.01	-108.3	5.84	-115.5	1.56	-120.1	-0.72	-156.7	-7.11	-236.2
303	4.63	-98.7	2.87	-141.8	1.26	-134.2	-6.14	-157.6	-8.96	10.7
304	12.88	-114.6	11.24	-125.8	3.67	-137.0	-1.47	-162.7	-8.16	-252.4
305	8.37	-127.1	7.36	-104.4	3.59	-98.2	-3.44	-159.4	-0.58	-226.1
306	11.68	-110.6	4.92	-104.7	3.87	-127.3	-3.62	-163.9	-7.88	87.7
307	8.38	-110.0	4.06	-101.1	0.46	-105.7	-0.37	-104.8	-5.46	-166.8
308	14.33	-88.5	5.17	-107.3	3.89	-107.7	-0.83	-115.6	-5.74	-163.6
333	18.82	-105.4	12.35	-89.3	8.41	-113.9	0.22	-133.2	-9.43	-155.9
334	12.43	-91.2	12.83	-99.8	7.41	-114.2	-0.31	-137.1	-10.45	-154.3
335	10.98	-92.7	9.87	-99.5	7.52	-120.9	-0.90	-159.4	-11.59	-216.8
336	14.32	-107.1	10.44	-102.8	6.15	-122.4	-1.65	-159.3	-11.75	-219.6
337	18.37	-95.4	9.73	-100.8	6.13	-126.7	-2.90	-172.4	-13.69	-229.8
338	10.59	-62.4	9.98	-100.1	5.93	-126.1	-3.33	-172.8	-13.51	-233.1
339	13.21	-133.5	13.36	-122.4	5.97	-141.0	-2.75	-186.1	-10.10	-262.3
340	13.08	-80.2	7.07	-112.2	5.74	-140.6	-2.87	-178.6	-10.79	85.9
341	16.06	-120.2	8.71	-95.6	5.61	-109.6	0.23	-159.2	-4.61	-263.8
342	11.32	-86.8	9.74	-105.5	6.99	-106.9	-0.08	-161.1	-6.72	-256.6
343	36.24	-126.1	7.37	-86.6	4.02	-117.9	-1.88	-167.5	-7.97	-257.0
344	13.50	-138.7	7.95	-105.2	5.93	-117.7	-1.55	-163.9	-7.14	-260.5
345	16.58	-83.4	11.46	-97.9	7.56	-104.4	0.12	-149.5	-7.86	-211.5
346	14.74	-75.4	13.27	-99.8	9.84	-113.5	1.44	-154.3	-9.98	-213.9
347	18.82	-90.6	11.67	-105.9	9.28	-117.2	1.27	-152.4	-6.43	-182.3
348	19.12	-130.5	13.68	-99.0	12.32	-112.4	2.54	-152.9	-6.50	-186.3
349	10.50	-120.6	6.94	-110.0	5.86	-125.5	-1.32	-168.3	-8.11	-238.1
350	10.74	-110.4	10.36	-122.8	6.51	-112.7	-0.72	-162.0	-9.00	-238.4
351	6.41	-141.4	7.02	-149.9	2.30	-150.1	-4.36	-211.8	-12.12	61.0
352	14.31	-153.3	7.22	-130.6	3.59	-155.2	-4.51	-209.8	-13.63	49.9
353	10.97	-141.4	9.17	-118.7	4.15	-146.5	-4.86	-205.0	-13.68	57.3
354	14.43	-94.6	6.80	-123.5	4.45	-148.3	-3.31	-194.0	-13.84	40.6
355	12.94	-135.1	8.46	-100.4	5.55	-114.2	-0.06	-155.6	-6.74	-243.2
356	15.25	-80.3	10.05	-99.3	5.84	-107.5	-0.34	-159.1	-8.70	-241.3
357	16.71	-87.1	8.91	-113.8	3.28	-117.3	-1.43	-178.4	-7.11	62.0
358	17.79	-85.4	5.11	-109.0	3.62	-107.2	-2.32	-176.3	-9.14	77.6
359	10.82	-83.7	5.32	-111.2	3.42	-118.5	-2.85	-184.4	-11.05	57.6
360	13.92	-89.0	6.60	-112.2	3.79	-119.6	-2.66	-183.1	-11.57	55.6
361	9.58	-122.6	4.24	-106.3	3.92	-108.3	-1.33	-170.0	-6.39	70.5

TABLE A-4. (CONTINUED)

RUN	FREQUENCY (RAD/SEC)									
	GAIN (dB) PHASE (DEG) OF YPYC (ROLL)									
	0.43		0.77		1.20		2.60		6.0	
362	10.32	-79.0	6.04	-80.3	2.85	-102.6	-0.19	-163.0	-5.42	76.4
363	11.74	-102.8	4.55	-96.3	2.21	-88.1	-0.71	-105.2	-6.43	-156.1
364	14.55	-83.5	6.47	-87.9	5.21	-98.2	-0.71	-125.6	-7.06	-162.5
365	8.78	-99.2	5.38	-91.5	3.01	-121.0	-3.45	-177.1	-12.18	66.7
366	6.32	-127.0	7.52	-102.3	4.34	-134.0	-2.16	-178.4	-10.59	73.4
367	12.03	-58.6	7.59	-103.7	6.48	-117.8	0.60	-161.2	-8.07	-236.1
368	14.26	-70.8	7.20	-102.8	6.05	-107.2	0.01	-159.0	-9.09	-245.2

TABLE A-4. (CONTINUED)

RUN	FREQUENCY (RAD/SEC) GAIN (dB) PHASE (DEG) OF YPYC (PITCH) 0.26		0.60		1.30		3.60		7.70	
369	18.09	-71.4	8.41	-79.5	5.74	-94.3	-0.46	-150.0	-10.03	-207.6
370	15.82	-80.0	10.63	-90.5	5.98	-98.5	-0.27	-152.5	-9.79	-213.8
371	12.57	-98.2	4.23	-85.8	2.28	-88.5	-1.84	-157.6	-2.88	86.0
372	9.39	-90.6	4.08	-88.5	1.15	-85.3	-1.92	-155.9	-5.54	-250.1
373	12.43	-85.6	4.42	-77.5	1.53	-87.1	-2.35	-156.5	-4.28	-264.7
374	24.27	41.6	18.58	-209.7	7.27	-175.4	-7.13	-185.3	-14.54	-216.2
375	23.94	-266.2	16.65	-173.6	7.61	-174.7	-6.30	-191.7	-14.62	-214.9
376	10.93	-89.3	6.76	-77.0	1.28	-97.2	-1.88	-155.6	-4.50	-269.5
377	10.98	-87.9	6.72	-84.4	1.46	-98.3	-2.30	-161.9	-6.79	84.7
378	6.46	-91.8	-1.58	-77.6	-5.14	-89.1	-7.13	-147.7	-7.81	64.5
379	9.64	-93.9	2.76	-89.4	-2.93	-96.0	-4.04	-122.7	-6.73	52.1
380	8.62	-96.3	3.12	-86.9	-2.01	-98.5	-5.93	-143.8	-6.66	66.4
397	22.59	-135.5	14.37	-127.8	10.01	-116.1	-2.68	-147.1	-8.04	-178.7
398	19.94	-133.9	17.85	-110.5	8.59	-114.8	-2.00	-143.9	-8.93	-174.6
399	17.54	-96.3	11.63	-95.9	5.53	-91.9	-0.99	-146.1	-7.96	-216.3
400	17.19	-110.8	9.99	-91.5	6.05	-92.1	-0.96	-143.6	-7.20	-217.4
401	10.87	-98.9	5.72	-89.0	1.94	-91.8	-2.14	-141.6	-7.45	-214.5
402	22.37	-136.3	6.75	-93.4	2.24	-82.2	-2.53	-125.2	-7.38	-225.1
403	21.49	8.0	17.52	-157.2	9.98	-168.1	-5.67	-184.0	-12.85	-228.5
404	16.16	-224.5	16.33	-175.6	7.05	-152.7	-4.32	-177.3	-9.86	-216.7
405	11.79	-132.3	5.05	-74.5	1.11	-86.1	-1.23	-121.8	-6.58	-201.8
406	16.74	-124.9	6.21	-90.8	1.96	-86.9	-1.70	-127.6	-6.74	-214.9
407	10.76	-118.6	6.13	-92.7	1.84	-79.0	-1.55	-120.4	-7.16	-208.9
408	9.45	-116.9	3.02	-87.5	0.80	-83.9	-1.43	-140.0	-3.21	-260.2
409	10.52	-108.5	6.28	-99.9	-0.21	-90.5	-4.56	-146.3	-2.34	-255.7
410	13.06	-98.4	4.27	-95.0	0.34	-91.6	-2.22	-151.8	-0.71	-269.3
411	19.82	-50.4	8.95	-92.1	2.47	-104.5	-2.75	-158.3	-2.01	-259.0
412	10.97	-111.5	7.40	-101.1	2.16	-97.5	-2.53	-151.3	-2.56	-265.8
413	10.57	-115.3	4.35	-92.1	-0.35	-88.7	-0.72	-144.4	-2.85	-268.9
414	15.48	-98.5	3.95	-96.5	1.68	-98.0	-2.31	-152.9	-2.88	-267.0
415	11.51	-100.2	3.34	-100.8	-0.98	-89.9	-3.61	-151.8	-1.17	72.5
416	14.88	-98.0	3.82	-90.0	-1.76	-84.4	-3.45	-140.4	-2.92	89.0
417	10.33	-91.0	3.75	-96.4	-0.91	-106.6	-5.72	-147.8	-5.32	58.0
418	11.90	-99.1	3.13	-103.7	-1.52	-100.5	-4.42	-156.7	-8.54	52.5
419	23.07	-153.9	14.36	-114.4	9.08	-122.4	-3.33	-148.4	-10.41	-159.3
420	18.97	-75.1	15.89	-124.3	8.64	-117.1	-3.44	-142.6	-9.68	-154.7
421	21.25	-181.8	13.71	-141.3	6.95	-167.9	-5.92	-182.5	-11.45	-212.0
422	15.56	17.6	18.89	-239.4	7.09	-170.1	-4.58	-180.6	-9.04	-218.6
423	14.83	-99.0	8.86	-97.1	3.00	-93.8	-3.54	-142.4	-8.51	-195.3
424	17.35	-132.9	6.92	-109.7	3.08	-90.4	-2.80	-138.3	-8.17	-191.0
425	6.49	-182.3	7.25	-177.9	7.58	-154.1	0.21	-161.5	-6.36	-193.8
426	6.80	-182.2	7.02	-179.6	6.84	-168.8	1.62	-162.9	-5.39	-185.3
427	10.84	-197.8	7.38	-190.9	3.07	-170.9	2.07	-161.8	-3.64	-180.4
428	11.21	-189.8	7.07	-182.5	9.05	-181.2	1.26	-160.2	-3.61	-179.3

TABLE A-4. (CONTINUED)

RUN	FREQUENCY (RAD/SEC) GAIN (dB) PHASE (DEG) OF YPYC (ROLL)									
	0.43		0.77		1.20		2.60		6.0	
381	13.98	-114.8	9.50	-111.9	5.59	-118.8	-1.73	-155.7	-11.85	-205.8
382	13.33	-117.2	8.54	-101.4	5.21	-112.8	-1.89	-149.4	-13.07	-204.8
383	12.82	-107.1	8.65	-119.7	4.36	-131.3	-4.24	-164.9	-13.40	-220.8
384	14.66	-119.5	9.97	-107.6	5.50	-132.5	-3.36	-167.2	-12.89	-222.1
385	14.75	-86.6	9.06	-90.5	6.73	-98.9	-0.36	-121.5	-7.78	-156.4
386	18.65	-91.9	14.42	-99.6	9.77	-119.2	2.92	-150.6	-7.60	-163.4
387	24.73	-77.3	8.16	-113.3	4.53	-134.6	-3.12	-167.9	-8.12	-256.3
388	14.04	-127.9	9.46	-117.9	3.53	-130.6	-2.35	-165.6	-9.51	-261.1
389	10.22	-100.1	7.03	-99.1	3.79	-107.7	-1.19	-153.3	-7.57	-241.2
390	11.10	-83.8	6.50	-105.5	4.84	-107.5	0.11	-146.1	-8.06	-245.6
391	9.62	-94.6	7.06	-107.1	4.55	-110.4	-2.70	-149.0	-12.42	-201.8
392	11.09	-99.4	8.26	-104.8	4.74	-117.2	-1.45	-149.6	-11.43	-217.1
393	16.09	-104.0	9.97	-129.3	5.40	-122.7	-1.87	-163.2	-9.75	-220.4
394	11.89	-92.3	8.64	-116.3	6.22	-127.4	-1.25	-157.8	-9.86	-206.9
395	15.74	-114.2	9.03	-103.5	4.97	-128.7	-1.85	-161.4	-9.94	-228.9
396	11.54	-79.2	9.50	-102.5	5.85	-121.1	-1.50	-160.7	-9.06	-222.4
397	17.68	-132.5	12.74	-104.6	9.85	-116.8	2.47	-148.3	-7.88	-181.1
398	18.43	-102.1	15.78	-106.8	11.29	-116.3	3.22	-148.4	-7.31	-181.2
399	18.82	-122.1	13.43	-103.6	10.53	-118.7	1.12	-150.8	-7.34	-182.8
400	17.69	-91.4	15.02	-104.0	9.95	-114.5	2.05	-147.2	-7.65	-179.6
401	16.22	-132.3	13.07	-99.1	8.12	-116.4	0.57	-157.8	-7.03	-220.8
402	12.49	-134.4	10.20	-98.4	6.17	-109.7	0.00	-158.5	-6.33	-215.6
403	22.64	-87.1	10.56	-106.7	8.65	-111.5	2.31	-155.6	-6.00	-232.5
404	13.56	-132.5	10.47	-116.4	6.63	-116.1	-0.37	-145.0	-6.17	-221.6
405	15.86	-101.1	9.73	-126.4	5.25	-108.5	-1.87	-176.3	-10.78	74.9
406	10.15	-88.8	6.93	-115.3	4.59	-123.2	-1.46	-167.0	-5.40	-261.5
407	11.46	-101.4	5.44	-97.1	4.33	-119.2	-1.07	-159.3	-4.82	-259.1
408	14.27	-104.5	9.44	-132.6	8.26	-132.5	-3.60	-172.7	-8.86	-243.7
409	13.84	-83.0	10.25	-137.7	5.37	-133.5	-2.56	-178.3	-7.83	-246.2
410	17.77	-104.8	10.36	-118.1	6.09	-145.6	-2.69	-186.7	-11.22	-249.1
411	18.03	-90.8	11.74	-103.1	8.35	-118.6	0.03	-156.0	-9.10	-240.1
412	17.24	-79.7	7.70	-106.2	5.99	-118.1	-1.44	-158.2	-8.80	-222.9
413	13.44	-87.6	8.73	-111.3	5.58	-108.9	-0.33	-157.4	-7.15	-226.8
414	17.73	-111.9	14.83	-99.9	7.16	-119.7	-0.01	-156.8	-10.07	-242.3
415	8.45	-66.4	9.19	-106.2	5.55	-118.7	-2.09	-170.1	-8.16	-263.1
416	15.11	-57.1	8.51	-94.8	4.38	-112.5	-0.85	-166.5	-7.37	-261.8
417	19.85	-165.5	7.72	-116.0	5.96	-123.9	-2.00	-163.6	-9.28	-241.0
418	11.94	-95.9	9.61	-98.8	4.56	-122.9	-2.03	-165.3	-11.57	-234.4
419	13.46	-79.9	11.57	-100.3	8.09	-116.2	-0.49	-154.2	-6.61	-222.9
420	17.94	-97.2	12.45	-102.9	7.11	-116.8	1.46	-151.1	-5.54	-217.9
421	10.41	-102.5	7.40	-112.2	5.70	-116.0	-0.21	-164.5	-3.22	-253.5
422	11.27	-129.4	6.79	-103.7	6.60	-119.7	0.73	-163.7	-6.21	-266.7
423	11.97	-128.0	9.61	-107.7	4.49	-120.3	-0.69	-162.8	-5.76	-258.1
424	13.85	-98.0	6.61	-107.7	4.93	-119.0	-1.47	-169.5	-6.85	87.2
425	7.08	-196.8	0.33	-177.6	-0.34	-152.3	-0.34	-152.3	-0.34	-152.3
426	-1.24	-190.4	7.47	-205.5	2.97	-55.9	2.97	-55.9	2.97	-55.9
427	11.75	-83.9	11.39	-133.3	4.96	-138.4	-2.82	-173.3	-11.24	-258.0
428	18.45	-97.4	10.77	-140.2	5.55	-144.5	-2.71	-175.0	-10.27	-251.1

TABLE A-4. (CONTINUED)

RUN	FREQUENCY (RAD/SEC) GAIN (dB) PHASE (DEG) OF YPYC (PITCH)									
	0.26		0.60		1.30		3.60		7.70	
470	18.72	-85.9	9.64	-93.6	5.16	-93.1	0.01	-148.4	-8.81	-220.3
471	21.86	-77.9	10.96	-90.8	5.95	-101.9	0.11	-149.1	-9.22	-216.2
472	18.59	-85.8	12.85	-100.5	6.26	-104.8	0.12	-149.5	-9.15	-218.9
473	19.46	-66.2	11.08	-92.2	6.17	-99.8	0.55	-144.6	-9.22	-223.7
474	18.25	-95.0	9.94	-99.5	3.31	-103.7	-0.95	-129.6	-9.29	-231.8
475	14.09	-101.6	6.88	-97.0	2.24	-98.4	-1.98	-114.1	-7.55	-225.7
476	14.09	-104.6	8.41	-90.7	3.75	-101.9	-2.13	-159.2	-4.32	-262.7
477	13.43	-105.1	8.82	-87.7	3.46	-101.1	-1.18	-156.6	-4.66	-254.6
479	17.49	-79.5	10.01	-92.3	4.20	-105.6	-0.54	-156.6	-3.40	-267.2
479	19.37	-92.7	8.13	-107.5	4.07	-103.9	-1.68	-156.7	-3.79	-268.6
480	7.45	-98.8	4.53	-82.8	1.31	-96.9	-0.57	-140.6	-3.45	85.8
481	15.41	-84.8	8.11	-97.2	2.97	-102.6	-1.14	-147.1	-2.63	-264.1
482	12.89	-101.5	9.94	-75.1	4.78	-126.5	-8.43	-189.1	-13.34	-267.4
483	17.63	-108.6	9.47	-87.7	7.20	-127.5	-6.49	-199.9	-13.35	-263.2
493	17.82	-86.9	8.25	-83.3	5.06	-90.1	-0.20	-143.8	-7.69	-218.1
494	17.38	-95.6	8.57	-74.3	4.71	-91.9	-0.41	-137.2	-7.66	-211.8
495	1.98	-75.7	-5.67	-77.2	-8.95	-50.4	-3.10	-84.7	-10.53	-246.7
496	2.68	-90.2	-2.39	-76.4	-8.60	-51.2	-5.98	-122.0	-8.61	-215.6
497	7.21	-129.0	-0.11	-72.9	-4.79	-78.0	-6.76	-133.1	-5.28	72.7
498	5.84	-96.0	-4.38	-81.4	-4.84	-77.2	3.44	-103.0	-5.92	74.2
499	0.43	-74.7	0.69	-99.0	-0.64	-75.9	-4.68	-156.8	-5.84	-264.5
500	9.02	-83.5	1.97	-89.5	1.74	-84.8	-8.46	-160.6	-4.78	-259.7
501	3.74	-185.8	5.09	-172.1	4.38	-166.2	-0.06	-162.3	-5.55	-178.7
502	6.55	-170.4	4.68	-160.5	5.76	-159.4	-1.58	-142.1	-5.37	-171.1
503	11.33	-109.9	2.21	-67.6	-0.59	-77.5	-1.16	-141.5	-1.63	84.4
504	7.11	-104.7	1.51	-72.8	0.19	-83.0	-4.25	-139.2	-0.63	72.2
505	11.06	-97.3	6.50	-100.9	3.07	-137.9	-7.12	-213.4	-13.58	55.0
506	6.81	-85.8	8.32	-64.9	5.31	-127.9	-6.41	-212.5	-13.57	47.8
508	16.77	-106.6	8.65	-111.0	5.90	-130.0	-4.34	-196.5	-6.42	64.6
509	12.86	-94.3	8.73	-98.0	5.65	-123.4	-6.80	-215.8	-13.20	67.0
510	14.19	-91.8	7.44	-88.3	3.05	-106.4	-3.39	-174.8	-7.43	-265.8
511	10.75	-87.9	5.76	-85.1	1.47	-100.5	-3.24	-170.5	-7.79	88.8
512	8.82	-104.2	2.78	-93.8	-0.88	-99.3	-4.85	-140.6	-4.96	62.1
514	17.11	-74.3	12.85	-96.3	7.54	-130.7	-6.09	-192.6	-13.22	-248.7
515	20.46	-71.0	14.52	-100.4	9.73	-133.4	-4.89	-190.0	-12.30	-258.8
522	23.09	-79.6	14.46	-104.8	7.58	-111.5	-3.89	-176.1	-6.98	-250.5
523	27.20	77.0	13.01	-90.6	5.54	-124.3	-4.38	-173.4	-8.88	-251.0
525	7.60	-103.7	4.73	-92.6	-0.86	-88.5	-2.55	-141.7	-2.30	-259.6
526	9.06	-119.2	4.05	-91.0	0.09	-92.4	-4.07	-150.9	-3.24	-252.3
527	8.49	-193.2	6.40	-180.0	4.78	-172.9	-0.48	-162.0	-4.21	-171.4
528	7.43	-187.6	6.31	-173.6	4.67	-161.7	-0.56	-162.1	-5.17	-175.8

TABLE A-4. (CONTINUED)

RUN	FREQUENCY (RAD/SEC) GAIN (dB) PHASE (DEG) OF YPYC (ROLL)									
	0.43		0.77		1.20		2.60		6.0	
485	16.29	-80.5	10.45	-98.3	7.12	-122.5	-0.66	-156.1	-11.12	-218.3
486	14.36	-79.6	10.02	-108.9	6.99	-122.8	-1.97	-157.5	-11.91	-211.5
487	14.92	-154.8	11.13	-155.2	5.30	-153.2	-5.42	-175.3	-13.10	-235.3
488	14.96	-123.8	13.23	-137.2	6.95	-153.1	-3.74	-178.5	-14.58	-233.6
489	28.45	-188.6	7.54	-124.8	5.03	-140.4	-1.80	-178.5	-8.31	87.4
490	14.84	-93.4	11.09	-134.9	3.26	-142.5	-4.01	-185.8	-12.21	-268.9
493	12.40	-84.4	11.09	-104.2	6.69	-116.5	-0.57	-158.0	-7.33	-234.6
494	12.60	-92.1	9.16	-105.7	6.79	-114.1	-0.45	-158.4	-9.13	-235.0
495	8.55	-122.9	4.43	-124.7	-2.33	-146.3	-11.27	-175.8	-19.56	-250.9
496	6.48	-104.4	1.58	-120.4	-1.87	-139.7	-10.75	-170.8	-21.73	-238.3
497	4.92	-116.2	0.73	-121.4	-0.11	-133.3	-7.37	-174.4	-24.57	73.7
498	5.50	-106.2	3.38	-121.1	-0.38	-141.6	-8.62	-186.1	-19.64	-259.8
499	15.00	-114.4	7.93	-125.9	2.80	-149.7	-5.43	-205.8	-15.28	45.1
500	7.88	-134.4	3.27	-129.9	2.14	-146.3	-6.47	-214.3	-16.14	48.7
501	-2.78	0.4	3.25	-153.8	1.36	-159.7	-5.53	-233.3	-16.04	-0.1
502	9.41	-96.2	8.87	-155.4	3.06	-158.1	-6.22	-232.8	-17.40	-18.9
503	9.64	-48.2	4.16	-121.1	0.38	-145.5	-11.87	-223.9	-18.46	22.6
504	18.70	-115.4	6.01	-99.3	2.55	-151.5	-5.97	-215.3	-16.65	22.9
505	3.79	-58.4	3.91	-107.1	2.21	-107.0	-2.47	-170.5	-10.02	68.9
506	9.88	-27.1	5.75	-98.5	3.11	-117.5	-3.17	-172.6	-11.21	63.2
517	18.07	-102.8	11.13	-99.4	8.66	-105.9	1.36	-127.5	-6.93	-149.9
518	13.18	-113.3	6.45	-120.1	4.39	-121.5	-2.36	-158.5	-8.56	-263.2
519	13.10	-90.8	6.72	-94.4	4.47	-113.7	-1.80	-158.3	-7.90	-248.2
520	13.64	-95.3	8.83	-104.7	5.91	-117.8	-0.88	-153.8	-9.81	-225.0
522	14.06	-97.2	11.02	-113.4	8.47	-128.8	1.42	-161.6	-5.15	-236.5
523	14.07	-101.4	9.39	-111.2	7.57	-123.0	-0.80	-159.2	-7.25	-238.9
525	16.29	-102.9	9.32	-106.7	6.65	-129.1	-0.38	-157.1	-7.90	-228.6
526	16.02	-119.8	9.31	-93.3	7.21	-112.6	-1.64	-163.8	-8.26	-249.6
527	19.88	-133.1	8.68	-121.2	5.93	-119.7	-1.64	-178.2	-7.21	-265.4
528	12.57	-13.2	8.21	-131.7	4.46	-124.0	-1.76	-176.7	-6.60	69.4

TABLE A-4. (CONTINUED)

RUN	FREQUENCY (RAD/SEC)									
	GAIN (dB) PHASE (DEG) OF YPYC (PITCH)									
	0.26		0.60		1.30		3.60		7.70	
530	19.00	−121.0	15.20	−77.7	8.62	−111.0	−1.14	−143.6	−11.14	−176.3
531	17.51	−95.5	14.81	−91.2	7.55	−109.2	−1.68	−139.5	−11.30	−176.1
536	23.88	−91.9	13.97	−164.8	5.86	−162.1	−6.00	−176.8	−14.08	−230.9
537	21.78	−208.6	16.70	−153.3	7.57	−165.3	−5.56	−186.8	−14.07	−238.6
542	6.96	−168.0	7.62	−172.9	6.40	−160.1	0.34	−158.7	−5.49	−181.7
543	7.45	−183.5	6.80	−161.3	5.91	−165.1	1.04	−161.7	−4.32	−170.2
558	22.71	−132.7	11.20	−102.4	4.34	−117.1	−5.90	−145.0	−15.00	−185.3
559	22.44	−111.4	11.25	−98.1	5.27	−115.9	−5.01	−150.0	−12.66	−184.5
563	8.53	−69.3	10.46	−113.8	1.49	−148.4	−5.76	−166.2	−11.04	−247.4
564	13.70	−104.3	10.08	−133.8	4.76	−162.2	−5.69	−181.9	−12.12	−257.3
565	6.52	−101.5	3.35	−87.1	−1.22	−82.5	−6.71	−117.4	−12.32	−180.4
567	7.75	−194.4	8.86	−175.6	6.41	−161.6	1.22	−164.2	−6.89	−171.7
568	6.61	−196.9	6.69	−174.3	5.90	−159.2	2.02	−162.7	−3.73	−178.4
569	8.28	−180.2	5.04	−170.0	4.47	−161.3	0.36	−163.1	−4.25	−178.4
570	7.52	−178.1	7.40	−176.3	4.90	−140.9	0.36	−152.8	−5.54	−183.8
571	10.38	−91.5	8.48	−166.8	4.90	−165.3	−6.97	−190.4	−15.31	−237.8
572	20.66	29.8	12.40	−179.2	5.00	−174.8	−4.95	−189.1	−11.86	−256.1

TABLE A-4. (CONTINUED)

RUN	FREQUENCY (RAD/SEC) GAIN (dB) PHASE (DEG) OF YPYC (ROLL)									
	0.43		0.77		1.20		2.60		6.0	
546	17.45	-85.8	14.31	-98.3	9.66	-116.3	2.44	-144.9	-8.02	-151.0
547	17.17	-90.6	13.22	-98.3	9.24	-115.8	0.86	-135.2	-8.63	-150.3
548	13.38	-96.8	14.24	-93.2	9.36	-120.4	0.90	-154.2	-8.49	-213.3
549	15.46	-64.6	13.50	-102.6	7.92	-119.5	-0.95	-153.3	-11.04	-209.6
550	11.89	-82.2	9.79	-121.6	4.47	-123.9	-3.46	-170.0	-8.62	-256.2
551	17.63	-72.6	11.19	-109.6	7.05	-129.1	-1.02	-158.5	-8.03	-253.9
552	14.71	-156.1	8.94	-141.5	4.70	-156.7	-5.07	-189.6	-10.48	86.7
553	16.10	-125.2	8.65	-142.5	5.29	-157.2	-4.52	-192.3	-11.56	88.8
554	7.66	-68.6	6.86	-98.2	4.04	-106.4	-1.29	-156.9	-8.63	-249.1
555	10.25	-93.3	7.62	-98.9	4.03	-115.8	-1.73	-153.6	-8.45	-239.7
556	15.45	-126.6	7.42	-126.6	3.20	-141.9	-4.81	-182.5	-8.96	-268.4
557	23.52	-76.9	8.54	-120.9	4.44	-146.5	-4.05	-186.0	-10.14	-263.6
558	13.54	-115.4	15.58	-94.9	7.24	-102.3	2.92	-134.0	-6.08	-168.9
559	14.26	-109.1	12.92	-95.6	8.66	-118.5	0.68	-146.3	-6.47	-172.9
560	18.42	-41.5	6.00	-78.6	7.71	-109.7	-0.91	-160.3	-8.98	-222.6
561	11.74	-96.4	7.07	-103.6	6.05	-111.5	-1.55	-156.5	-8.88	-233.7
562	12.21	-100.3	8.84	-118.4	2.62	-121.4	-5.06	-167.9	-8.08	-261.3
563	8.43	-115.3	5.04	-103.7	2.71	-112.5	-2.68	-164.7	-6.94	79.7
564	9.87	-127.0	8.60	-85.8	4.01	-120.3	-2.93	-177.6	-7.11	61.7
565	12.36	-138.9	2.72	-126.6	-0.05	-141.6	-6.93	-185.3	-14.91	52.7
566	12.71	-137.3	4.90	-123.4	1.33	-141.8	-5.03	-187.2	-14.40	-310.1
567	10.55	-124.1	6.95	-107.9	2.71	-96.6	-2.45	-123.3	-8.13	-170.2
568	4.34	-108.6	2.76	-76.9	-0.78	-78.4	-3.59	-117.6	-12.88	-176.5
569	16.50	-187.6	7.16	-114.3	3.32	-142.4	-3.23	-178.4	-9.66	82.2
570	11.12	-106.3	5.69	-133.8	1.91	-128.2	-4.32	-195.2	-14.04	46.9
571	17.61	-82.0	6.16	-90.3	-0.61	-80.2	0.50	-120.1	-7.63	-164.4
572	8.76	-80.3	4.47	-43.5	2.30	-87.5	-2.53	-111.5	-7.69	-156.6

TABLE A-4. (CONTINUED)

RUN	FREQUENCY (RAD/SEC) GAIN (dB) PHASE (DEG) OF YPYC (PITCH)									
	0.26		0.60		1.30		3.60		7.70	
573	20.20	-81.2	16.64	-97.6	10.81	-115.7	0.14	-146.5	-9.06	-176.3
574	24.79	-124.2	17.64	-112.6	9.21	-116.7	-1.89	-141.7	-10.41	-176.6
575	19.46	-111.6	10.86	-99.3	6.19	-102.4	-0.54	-149.0	-7.33	-234.0
576	18.75	-62.0	11.21	-84.9	5.48	-96.6	0.09	-150.4	-6.79	-229.2
577	14.96	-111.0	9.20	-73.0	3.07	-103.8	-0.57	-157.1	-4.33	88.0
578	16.20	-144.9	6.72	-94.6	3.40	-100.9	-1.05	-153.7	-4.99	-261.4
579	11.62	-90.9	6.13	-100.8	0.48	-111.9	-2.76	-152.4	-7.08	65.5
580	11.19	-109.5	4.29	-92.7	0.05	-105.9	-5.95	-171.8	-8.67	76.1
581	13.08	-130.6	15.00	-159.3	5.99	-155.0	-8.58	-177.1	-14.84	-219.7
582	25.00	-170.8	18.41	-127.5	6.35	-158.0	-7.45	-193.6	-15.99	-240.6
583	16.08	-111.5	9.22	-80.7	5.42	-94.3	-1.92	-149.0	-6.38	-230.0
584	14.80	-75.2	9.51	-86.5	5.62	-99.4	-0.69	-147.9	-7.01	-226.7
593	15.10	-84.7	12.24	-74.6	5.03	-100.7	-4.06	-138.7	-10.54	-172.9
594	16.57	-12.7	9.15	-100.6	5.31	-109.8	-3.06	-137.5	-10.34	-176.5
595	12.52	-101.5	9.80	-96.9	4.86	-107.9	-0.83	-157.7	-6.71	-230.6
596	14.14	-108.9	5.19	-76.1	4.79	-94.7	0.45	-150.3	-5.14	-235.2
597	11.93	-94.0	4.76	-61.2	3.06	-100.2	-1.60	-156.9	-2.51	-261.6
598	7.64	-111.4	5.24	-75.4	3.95	-92.0	-1.57	-154.3	-3.65	-263.0
599	-3.41	-80.0	-4.91	-70.6	-5.86	-67.5	-2.67	-129.0	-4.48	70.2
600	1.87	-100.5	-5.93	-71.1	-8.19	-63.5	-6.50	-134.5	-5.94	56.7
601	8.24	-105.7	2.62	-96.2	-0.48	-90.3	-4.19	-132.4	-6.50	50.8
602	9.47	-112.4	0.92	-88.5	-1.73	-103.6	-1.16	-141.8	-4.55	55.6
603	14.87	-81.1	6.58	-91.6	2.17	-106.1	-3.38	-160.8	-5.14	-258.8
604	13.02	-45.3	6.49	-78.0	2.25	-103.9	-3.38	-154.4	-4.22	-257.5
605	5.35	85.4	2.93	-108.1	1.22	-155.2	-13.19	-154.8	-15.19	-227.2
606	20.94	-52.7	8.83	-153.8	3.07	-158.1	-13.07	-181.4	-15.57	-218.9

TABLE A-4. (CONTINUED)

RUN	FREQUENCY (RAD/SEC) GAIN (dB) PHASE (DEG) OF YPYC (ROLL)									
	0.43		0.77		1.20		2.60		6.0	
585	14.13	-98.4	10.98	-88.4	7.06	-113.4	-0.51	-155.0	-10.34	-222.4
586	11.74	-82.2	10.58	-87.1	7.30	-114.0	-0.64	-154.7	-9.91	-219.0
587	7.38	-85.2	7.31	-96.6	5.31	-108.7	-2.20	-155.7	-8.24	-253.3
588	10.08	-67.7	5.83	-101.8	2.59	-114.5	-4.45	-163.3	-11.85	-252.2
589	15.53	-163.2	20.39	-94.7	4.79	-155.1	-3.77	-183.8	-11.35	79.9
590	18.50	-70.1	13.13	-115.5	5.34	-149.1	-3.34	-186.3	-10.38	80.3
591	13.88	-92.4	11.59	-90.2	6.66	-114.5	-1.01	-152.7	-10.09	-224.1
592	17.62	-91.3	9.55	-98.4	6.47	-117.0	-1.09	-154.4	-10.61	-223.6
593	15.89	-30.5	6.39	-104.2	4.96	-114.1	-1.34	-166.8	-10.08	-252.9
594	10.49	-71.0	8.27	-116.8	5.90	-99.9	-0.98	-158.6	-9.24	-250.5
595	10.47	-70.4	7.55	-119.0	4.85	-118.1	-3.27	-164.5	-13.91	-253.4
596	11.54	-61.4	6.40	-99.9	3.64	-118.1	-3.87	-173.1	-13.47	-253.1
597	9.49	-101.2	10.17	-127.7	2.93	-123.2	-4.60	-183.2	-13.10	67.6
598	10.54	-103.2	8.02	-120.5	3.95	-137.6	-3.80	-204.4	-13.99	46.2
599	6.82	-158.7	4.10	-130.6	-2.22	-154.6	-9.63	-211.5	-19.09	75.5
600	7.85	-110.2	1.82	-119.3	-2.95	-142.8	-11.45	-190.0	-18.65	72.0
601	10.58	-106.5	6.87	-93.7	0.61	-122.5	-7.51	-167.3	-16.74	-264.7
602	6.13	-104.4	4.36	-87.7	0.59	-130.9	-6.85	-185.7	-16.47	-262.0
603	11.87	-57.8	6.61	-118.6	4.11	-112.1	-2.96	-168.0	-10.66	-262.9
604	14.10	-73.2	4.97	-109.7	2.85	-113.5	-4.37	-166.3	-11.99	-256.4
605	6.82	-108.6	5.48	-73.0	0.15	-84.0	-3.21	-155.7	-9.12	-225.8
606	10.03	-83.0	6.93	-113.4	4.86	-113.7	-1.28	-155.1	-6.97	-226.9

TABLE A-4. (CONTINUED)

RUN	FREQUENCY (RAD/SEC) GAIN (dB) PHASE (DEG) OF YPYC (PITCH) 0.26		0.60		1.30		3.60		7.70	
607	21.19	-68.6	12.61	-95.4	6.57	-105.0	-3.51	-139.5	-10.14	-182.3
608	21.15	-75.3	13.53	-88.9	6.43	-106.5	-2.90	-137.4	-12.25	-194.1
609	18.32	-73.0	12.38	-93.8	6.53	-109.4	-3.14	-141.3	-11.31	-187.2
610	15.53	-109.9	8.45	-89.1	4.36	-95.6	-1.74	-157.0	-7.74	-240.2
611	16.83	-88.7	7.69	-92.2	3.40	-94.2	-1.45	-154.5	-9.60	-252.1
612	19.37	-178.1	12.07	-144.5	5.39	-152.8	-6.90	-175.4	-14.86	-214.4
613	21.83	82.4	12.81	-171.5	4.62	-154.4	-7.46	-186.2	-16.55	-216.8
614	9.45	-92.6	5.50	-90.6	1.42	-93.8	-1.83	-158.1	-4.90	84.6
615	11.39	-75.8	4.73	-82.2	0.44	-90.5	-3.41	-159.4	-8.81	74.6
616	5.64	-183.5	5.85	-168.6	5.32	-165.4	-1.21	-157.6	-4.40	-170.9
617	8.32	-180.6	6.12	-171.6	5.60	-162.9	0.56	-160.4	-6.01	-180.2
618	13.35	-117.5	9.08	-97.0	0.80	-112.1	-5.82	-158.1	-5.60	69.0
619	13.65	-92.1	7.21	-91.8	-0.13	-110.3	-4.60	-159.7	-11.05	35.4
620	12.20	-77.4	4.83	-84.2	0.34	-96.9	-3.52	-168.4	-10.06	-261.5
621	9.79	-90.9	5.67	-90.4	0.02	-99.6	-3.33	-166.6	-8.71	88.6
632	19.51	-206.4	11.78	-109.6	5.61	-114.1	-3.17	-133.6	-10.66	-172.8
633	19.51	-189.9	12.03	-114.5	6.78	-113.7	-2.93	-140.9	-10.72	-168.9
634	16.94	-149.2	7.60	-98.1	2.62	-88.9	-1.44	-146.9	-7.03	-225.9
635	11.34	-119.3	8.22	-90.9	3.21	-91.4	-2.33	-138.6	-6.69	-223.5
636	9.52	-69.0	-0.41	-97.6	-3.93	-88.1	-9.59	-157.4	-4.71	-264.6
637	13.04	-136.4	4.39	-96.2	-2.02	-79.9	-4.77	-181.0	-6.47	49.8
638	14.61	-186.6	18.47	-158.1	5.51	-164.0	-8.49	-176.3	-10.92	-211.5
639	11.89	23.1	20.93	-255.8	6.40	-161.2	-6.23	-178.4	-11.66	-224.2
639	11.89	23.1	20.93	-255.8	6.40	-161.2	-6.23	-178.4	-11.66	-224.2
640	11.02	-99.4	4.27	-93.7	0.27	-91.3	-4.24	-153.6	-2.72	-253.9
641	14.62	-84.9	1.02	-89.4	0.85	-83.1	-3.24	-153.4	-2.16	-257.4
642	19.96	-149.0	19.13	-252.2	7.21	-168.3	-5.28	-177.3	-11.17	-213.3
643	25.27	-155.6	25.91	-237.1	9.56	-161.0	-4.53	-181.3	-12.22	-224.2
644	-4.76	-97.3	-13.86	-73.7	-8.34	-104.5	-13.47	72.6	-2.94	-265.9
645	4.79	-104.7	-4.31	-88.8	-7.95	-78.6	-6.51	-67.0	-6.72	84.9
646	6.30	-184.4	4.12	-176.9	5.17	-158.2	-1.01	-156.3	-5.14	-174.7
647	5.11	-178.6	4.96	-175.3	4.39	-157.5	-1.07	-163.7	-5.00	-168.6
648	7.70	-15.3	13.65	-125.6	8.92	-162.3	-3.75	-172.5	-9.35	-210.0
649	18.62	-76.4	11.87	-167.4	7.46	-173.7	-4.61	-179.2	-11.70	-212.7

TABLE A-4. (CONCLUDED)

RUN	FREQUENCY (RAD/SEC)									
	GAIN (dB) PHASE (DEG) OF YPYC (ROLL)									
	0.43		0.77		1.20		2.60		6.0	
622	17.63	-88.2	11.89	-99.9	8.69	-112.2	0.52	-143.1	-8.27	-167.6
623	14.71	-83.3	11.96	-108.1	8.01	-109.9	1.13	-130.5	-8.86	-157.1
624	14.31	-109.6	10.14	-104.9	5.99	-111.9	0.54	-152.2	-10.78	-231.9
625	15.31	-96.7	8.42	-105.5	5.77	-110.7	-1.87	-150.8	-11.12	-224.9
626	9.16	-93.6	8.62	-105.6	4.33	-119.8	-1.06	-157.7	-6.20	-244.5
627	10.59	-95.4	6.99	-109.0	3.82	-117.7	-1.99	-161.5	-8.77	-241.9
628	17.68	-129.6	8.83	-125.3	4.27	-151.3	-3.59	-180.0	-10.71	-266.6
629	13.34	-137.1	7.26	-126.0	3.25	-138.8	-3.77	-178.3	-10.05	-264.2
630	9.61	-81.3	4.58	-96.5	3.56	-114.1	-2.35	-159.5	-10.07	-244.0
631	9.83	-100.1	8.38	-107.2	4.95	-116.2	-1.00	-159.0	-7.82	-251.3
632	13.66	-111.1	11.13	-99.3	6.02	-104.6	-0.81	-121.7	-6.62	-171.5
633	17.34	-123.4	10.49	-99.4	7.26	-101.8	2.33	-132.3	-7.92	-168.0
634	12.39	-78.2	7.44	-107.4	6.51	-116.1	-1.09	-163.9	-7.88	-220.6
635	14.63	-105.1	7.65	-103.9	4.93	-122.6	-1.63	-158.2	-8.84	-224.6
636	17.87	-133.0	8.03	-108.1	5.03	-125.0	-0.40	-158.8	-8.38	-232.6
637	12.75	-125.6	8.74	-103.3	6.00	-119.8	-0.85	-161.7	-7.74	-224.8
638	9.84	-98.5	6.34	-108.0	4.50	-133.6	-1.47	-165.2	-7.33	-249.3
639	11.45	-128.7	5.80	-104.1	3.59	-128.9	-5.40	-166.5	-8.31	-261.4
639	11.45	-128.7	5.80	-104.1	3.59	-128.9	-5.40	-166.5	-8.31	-261.4
640	10.39	-106.5	7.71	-103.6	3.61	-125.5	-3.52	-165.8	-9.66	87.6
641	12.92	-130.3	6.85	-98.4	3.26	-127.0	-2.00	-163.6	-9.64	-268.2
642	12.60	-84.0	10.66	-82.0	3.97	-93.0	-2.42	-116.2	-7.62	-162.8
643	13.28	-105.5	8.82	-101.7	5.22	-107.5	-0.07	-133.7	-7.48	-145.6
644	11.66	-162.9	5.40	-137.7	0.70	-150.6	-6.74	-189.8	-15.07	-268.3
645	9.69	-142.4	5.52	-135.0	2.77	-148.3	-6.18	-185.4	-10.09	86.6
646	13.38	-127.5	7.72	-113.1	4.22	-126.5	-2.14	-175.2	-9.14	89.3
647	13.29	-89.8	8.82	-123.5	5.02	-135.5	-2.78	-182.8	-8.89	75.2
648	17.16	-131.1	7.87	-84.2	4.46	-116.7	1.31	-141.7	-5.28	-227.8
649	12.70	-105.8	10.92	-106.2	5.21	-114.5	-0.94	-149.4	-7.93	-224.3

APPENDIX B

DOCUMENTATION OF LAMARS MOVING-BASE SIMULATION

A detailed record of the moving-base simulation performed on the Large Amplitude Multimode Aerospace Research Simulator (LAMARS) at Wright-Patterson AFB, OH, during February and March of 1989 is presented in this Appendix.

The experimental program conducted on the LAMARS was focused on assessing the effect of multiple axis degradations on pilot opinion a d performance. This study greatly expanded the existing data base on multiple axis degradations using a high fidelity motion-base simulator. In addition, it provided the opportunity to assess the effect of multiple axis degradations on pilot performance and opinion using different evaluation tasks, including a managerial side task.

Computer code for measuring performance parameters and system describing functions, developed by STI and used for the preliminary fixed-base study (Appendix A), was provided to the Air Force and installed on the LAMARS. This made possible the measurement of the pilot performance data needed for this study.

A. SIMULATION OVERVIEW

The LAMARS is a six degree-of-freedom high fidelity motion-base simulator. Motion capabilities of the LAMARS allow large accelerations in all six degrees of freedom. Aircraft modeling and HUD display generation were performed by digital computers with an update rate of 25 msec. A 1:15,000 scale terrain board equipped with a computer controlled, optical probe equipped television camera was used for visual flying tasks. A sky-earth projector provided a visual horizon at all times.

The general layout of the cockpit is shown in Fig. B-1. It included a McFadden center-stick and a quadrant throttle (not shown in Fig. B-1). The Multi-Panel Display (MPD) positioned on the upper left hand side of the cockpit panel was to be used for generating a managerial-type side-task. Control of the cursor on the MPD was through a finger-operated button on the throttle lever.

Two evaluation tasks were designed for this experiment. The first was a precision pitch and roll attitude and airspeed compensatory HUD tracking task identical in nature to the pitch and roll attitude tracking task evaluated on the fixed-base simulation (Appendix A). The airspeed tracking loop was added in this study to further divide the pilot's attention. The task could consist of single axis tracking in any of the three axes, dual axis tracking in any combination of axes, or combined tracking of all three axes. Separate and unique sum-of-sine wave disturbance functions were injected into each loop to generate tracking errors. The uncoupled pitch, roll and airspeed loop structures were identical to that used in the fixed-base simulation (Appendix A) and are shown in Fig. B-2. The tracking display was a HUD with modified symbology (Figure B-3).

All elements of the loops (Fig. B-2) together with the DIGital Describing Function Analyzer (DIGDFA) software were implemented on the digital computer driving the LAMARS. The DIGDFA software measured pilot performance parameters (signal mean and rms magnitudes) and system open- and closed-loop describing functions.

The second evaluation task in this experiment was a low-level visual flying task using the LAMARS terrain board. Data for this task consisted of pilot ratings and strip-chart recordings of trajectory time histories.

As stated earlier, a sidetask was designed using the MPD in the cockpit (Fig. B-1). This task proved difficult, if not impossible, to perform together with the tracking task due to the high workload of the tracking task and difficulties in operating the throttle-mounted cursor controller (finger-actuated button).

B. AIRCRAFT DYNAMICS (CONTROLLED ELEMENT)

Aircraft dynamics were modeled on a digital computer using simple, linear transfer function dynamics. Longitudinal response to control inputs (δ_e) was represented by the constant-speed short-period approximations as shown below (units of rad, ft, and s).

$$\frac{\theta}{\delta_e} = \frac{M_{\delta_e} \cdot (s + 1/T_{\theta_2})\ e^{-\tau_1 s}}{s^2\ [s^2 + 2\zeta_{sp}\omega_{sp}s + \omega_{sp}^2]}$$

$$\frac{w}{\delta_e} \doteq \frac{U_o \cdot M_{\delta_e}\ e^{-\tau_1 s}}{[s^2 + 2\zeta_{sp}\omega_{sp}s + \omega_{sp}^2]}$$

The primary variables in pitch were ζ_{sp} and τ_1, with secondary variations in ω_{sp} and $1/T_{\theta_2}$. A few configurations investigated different response-types.

For pitch-only or pitch/roll evaluations, airspeed was free to vary as shown below (airspeed in ft/s).

$$\frac{u}{\delta_e} = \frac{-M_{\delta_e}\ g/T_{\theta_2}\ e^{-\tau_1 s}}{s^2\ [s^2 + 2\zeta_{sp}\omega_{sp}s + \omega_{sp}^2]}$$

When airspeed tracking (using throttle) was included as an evaluation task, speed varied only in response to the disturbance function in the speed axis. The airspeed-to-throttle transfer function was as shown below (airspeed in ft/s).

$$\frac{u}{\delta_T} = \frac{X_{\delta_T}/T_E\ e^{-\tau_3 s}}{s(s + 1/T_E)}$$

where T_E is the added engine lag in seconds.

For the lateral responses, the primary variables were the frequency of the roll subsidence mode, $1/T_R$, and the value of time delay, τ_2. The spiral was assumed to be neutral ($1/T_s = 0$) and the dutch roll well-behaved with a damping ratio of 0.4 and an undamped natural frequency of 2 rad/s. Lateral response to control inputs (δ_a) was represented by the following transfer functions ($U_o = 422$ ft/s and $g = 32.2$ ft/s^2; units of rad, ft, and s)

$$\frac{\phi}{\delta_a} = \frac{L_{\delta_a}\ e^{-\tau_2 s}}{s(s + 1/T_R)}$$

$$\frac{r}{\delta_a} = \frac{(g/U_o)\ L_{\delta_a}\ [s^2 + \omega_d^2]\ e^{-\tau_2 s}}{s(s + 1/T_R)[s^2 + 2\zeta_d\omega_d s + \omega_d^2]}$$

$$\frac{\beta}{\delta_a} = \frac{2(g/U_o)\, L_{\delta_a} \zeta_d \omega_d\, e^{-\tau_2 s}}{s(s + 1/T_R)[s^2 + 2\zeta_d \omega_d s + \omega_d^2]}$$

All other parameters used in the simulation were computed from these elementary transfer functions. Trim angle-of-attack was assumed to be zero.

The aircraft was perfectly coordinated and rudder pedals were not activated throughout the experiment.

The transfer functions used by the simulation software for the modeling of the aircraft longitudinal and lateral dynamics for all the configurations evaluated in this experiment are listed in Table B-1.

The time delay values for the primary configurations as implemented on the software model (Table B-1) are considerably different from that quoted in the main text of this report. This is due to the combined effect of the computer and display update rates which was equivalent to a pure time delay of approximately 0.033 sec. The time delay included in the software model was therefore adjusted to maintain the overall forward-loop time delay (approximately) at the value required by the configurations. Time delay was implemented in the digital simulation using a second-order Pade approximation. The effects of digital simulation time delays on the experimental configurations will be further discussed in the following section on the experimental configurations.

C. DISPLAY AND TASKS

Two different HUD displays were used for the two evaluation tasks. The HUD symbology for the tracking task is shown in Fig. B-3.

The HUD tracking task required the pilots to attempt to null errors in pitch, roll or airspeed and any combination, in the presence of pseudo-random disturbances applied directly to the output of the controlled element (Fig. B-2). For single or dual axis evaluations, the dynamics in the axis or axes not being evaluated were "frozen" and the control inputs

into these axes were ignored. The displayed error in the axis or axes not being evaluated therefore remained fixed at zero.

Six-degree-of-freedom motion effects were included in the simulation. For single axis HUD tracking evaluations in pitch, rolling and lateral motions were inhibited while pitch and heave motions were as dictated by the aircraft dynamics (shown in the preceding section). For single-axis HUD tracking evaluations in roll, pitch and vertical path dynamics were constrained while rolling and lateral motions remained unconstrained. Throttle-to-pitch and Throttle-to-path dynamic coupling were not being simulated, so throttle movement affected only surge motion to simulate airspeed changes.

The tracking task lasted approximately 75 sec in each axis. Data was recorded for 63 sec and the extra time was used as pilot "warm-up" and "cool-down" time. Pitch, roll and airspeed tracking runs were of identical duration whether run single axis, dual or combined.

Desired performance for the HUD tracking task required extended periods of operation with pitch, roll, and airspeed errors of less than ±2.5 deg, ±15 deg, and ±2 ft/s, respectively. Minor excursions outside these boundaries were permitted for desired performance if the pilot judged that they were caused by the disturbance function and that recovery was immediate and effective. Adequate performance required pitch, roll and airspeed errors of less than ±5.0 deg, ±30 deg, and ±4 ft/s. Desired and adequate performance bounds were the same for single-, dual-, or three-axis tracking.

The HUD symbology used for the low-level visual flying tasks is shown in Fig. B-4. Three tasks, representative of aggressive, high-speed (250 kt) low altitude (below 700 ft AGL) flight, utilizing the 1:15,000 scale terrain board, were devised. Figures B-5 and B-6 show sketches of the ground tracks and altitude profiles for these tasks. The Dolphin task (Fig. B-5) was intended to emphasize longitudinal dynamics by requiring precise attitude and altitude changes. Each run started at an altitude of 1000 ft above runway elevation (about 1100 ft AGL at the starting point), approximately 7.5 nmi from the threshold of the reference runway. The task required descents by locating ground-reference points and diving

toward these points. A velocity vector symbol on the HUD (Fig. B-4) was used as an aircraft reference. All climbs were at 5 deg of pitch attitude. The task ended with a flare at 150 ft above the runway and level flight down the runway. Desired performance required all altitudes within ±50 ft and acquisition of the HUD waterline mark (climbs) or ground reference point (dives) with the velocity vector with no overshoots greater than one diameter of the flight path marker. Adequate performance required altitudes within ±100 ft with no overshoots greater than two diameters of the flight path marker on climbs and dives. There were no lateral performance requirements for the Dolphin task.

The Slalom task emphasized lateral control (Fig. B-6). This task required steep turns by reference to landmarks, ending in a series of lateral sidesteps across the runway. The slalom required a constant altitude of 800 ft until the final turn, where a descent to 150 ft was performed. Since the intent was to emphasize lateral control, altitude limits for desired performance were relaxed to ±100 ft and adequate to ±200 ft. No specific quantitative limits were placed on roll control, but desired performance required smooth precise turns with no appreciable overshoots or sluggishness in bank.

The Combined task required coordinated pitch and roll control, combining the altitude profile of the Dolphin and the turns of the Slalom (Fig. B-6). Performance limits were those described for the separate tasks.

D. STICK

A McFadden center stick was used for pitch and roll control. The longitudinal and lateral characteristics of the stick are shown below. Linear force/displacement gradients were used in both axes. Breakout forces of 0.5 lbs and 1.5 lbs were included in the longitudinal and lateral axes, respectively. The stick force gradients and dynamics were verified using X-Y plots of stick force versus displacement and step responses.

$$\frac{\delta_{e_s}}{F_{e_s}} = \frac{0.42}{\left[\frac{s^2}{(17)^2} + 2\,\frac{(0.4)}{(17)}\,s + 1\right]}\ \frac{\text{inch}}{\text{lb}}$$

$$\frac{\delta_{a_s}}{F_{a_s}} = \frac{0.30}{\left[\frac{s^2}{(17)^2} + 2\,\frac{(0.4)}{(17)}\,s + 1\right]}\ \frac{\text{inch}}{\text{lb}}$$

Stick displacement sensing was used throughout the experiment.

A position control quadrant throttle was used for airspeed commands.

E. DISTURBANCE INPUTS

The pseudo-random pitch and roll disturbance functions were composed of the sum of seven sine waves in each axis. The airspeed disturbance function was composed of the sum of four sine waves. The composition of the pitch, roll, and airspeed disturbance functions, together with the rms magnitudes and time histories of the signals, are presented in Figs. B-7, B-8, and B-9.

As in the fixed-base simulation (Appendix A), the magnitudes of the sine wave components shown in Figs. B-7 through B-9 were designed to ensure that reliable describing function data was obtained. The phasing of the sine wave components in all three axes was randomly varied to change the time histories of the disturbance functions without affecting their spectra or rms magnitudes. This prevented the pilots from "learning" the distu oance functions and departing from compensatory tracking to precognitive behavior.

The use of even harmonics in any disturbance function was avoided to construct a signal with pseudo-random appearance and there were no common frequencies in the pitch and roll disturbance functions. The bandwidths of the pitch and roll disturbance functions were designed to be lower than the expected pilot/vehicle crossover frequencies in those axes.

The airspeed disturbance function was designed to force the pilot to divide his attention between two regions of the display (Fig. B-3) and two manipulators without adding unreasonably to his workload. Accordingly, the bandwidth of the airspeed disturbance function was designed to be significantly lower than the pitch and roll functions. The airspeed disturbance function resembled a very low frequency speed drift (Fig. B-9).

A very limited series of evaluations was performed with a lower frequency roll disturbance function. These results were too limited to be analyzed and hence the characteristics of this disturbance function are not documented here.

F. EXPERIMENT PROTOCOL

The pilots were allowed to evaluate each configuration through a period of unconstrained flight and select control sensitivity in the axes being evaluated (with the exception of throttle sensitivity, which was fixed) before performing the evaluation task. The exception to this format was a limited series of runs performed for one pilot (Pilot W) where pitch and roll sensitivity were fixed by the experimenter. At least two runs were performed for each configuration before assigning a pilot rating and dictating pilot comments. Control sensitivity adjustments between runs were encouraged to ensure that this was not a factor in the pilot ratings. The Cooper-Harper handling qualities rating scale was used.

The configurations were presented in a pseudo-random sequence. Single axis evaluations for both pitch and roll (or the Dolphin and Slalom for the visual flight task) were performed first and were followed by dual axis evaluations (or the Combined task for the visual flight task) using various combinations of the single axis configurations. Single- and dual-axis evaluations for a given pilot were performed on the same day whenever possible, to minimize the possibility of day-to-day variations in pilot rating.

In the initial series of runs for a pilot on a given day, configurations were usually presented in increasing order of difficulty in order to "calibrate" the pilot in terms of required compensation. After this initial stage configurations were presented in a random order.

G. PILOTS

Pilot B - Major, U. S. Air Force, currently assigned to 4950th Test Wing (WPAFB). He has 2600 hours on heavy transport aircraft and 450 hours on high performance jet trainers. No previous simulator experience or exposure to flying qualities evaluations.

Pilot H - Engineering Test Pilot and experienced flying qualities evaluation pilot. Holds fixed-wing single- and multi-engine and helicopter ratings. He is also a qualified fixed-wing instructor pilot. Flying experience includes over 4000 hours on general aviation aircraft. He has extensive experience on both fixed- and motion-base simulators, and was a subject on the STI fixed-base simulation (Appendix A).

Pilot M - Flying Qualities Engineer and general aviation pilot. Holds single-engine fixed-wing rating with 290 hours on general aviation aircraft. Experienced in flying qualities evaluations in both fixed- and moving-base simulations. He was a subject on the STI fixed-base simulation (Appendix A).

Pilot S - Major, U. S. Air Force. Test Pilot School graduate currently assigned to 4950th Test Wing (WPAFB), with 2900 hours on heavy tanker aircraft and 300 hours on a variety of high performance jet aircraft.

Pilot V - Flying Qualities Engineer and active pilot in Air Force Reserves, with 2200 hours on heavy transport aircraft and 150 hours on high performance jet trainers.

Pilot W - Captain, U. S. Air Force. Test Pilot School graduate currently assigned to F-111 Joint Test Force (Edwards AFB, CA). He has 1025 hours on fighter aircraft and 225 hours on high performance jet trainers.

H. CONFIGURATIONS

A complete listing of the pitch, roll and airspeed configurations evaluated in this simulation is presented in Table B-2.

As mentioned previously in the discussion of the simulated aircraft dynamics, a nominal time delay of 0.033 sec in the simulation was unavoid-

able due to computer and display update rates. The forward-loop pitch or roll attitude-to-stick dynamics for the k/s configurations in pitch (configuration 1) and roll (configuration J) therefore included this time delay. Since the nominal time delay was approximately the same as that called for in pitch configuration 2, no time delay was included in the aircraft model for this case (Table B-1), which made the overall pitch attitude-to-longitudinal stick time delay approximately that shown in Table B-2. For configurations where the time delay desired is greater than the nominal time delay, the residue was included in the simulation model as a second-order Pade approximation. For example, time delays of 0.167 sec and 0.034 were included in the pitch and roll forward loops in the simulation model for pitch Case 4 and roll Case B, respectively.

I. RESULTS

Table B-3 lists a run log for the simulation. A summary of all the pilot ratings for all configurations by all pilots for the two evaluation tasks is shown in Figures B-10 and B-11.

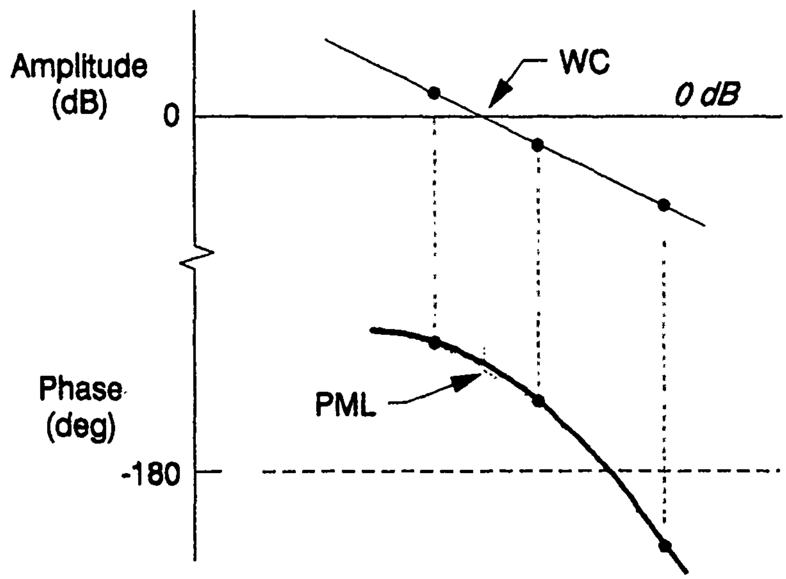
Pilot ratings and performance summaries are presented in Table B-4. The configurations are as listed in Table B-2. The pilot performance measures are based on the human pilot crossover model (Ref. B-1). A listing of these measures together with accompanying explanations are provided below.

The open-loop pilot/vehicle describing functions ($Y_pY_c = \theta/\theta_E$, ϕ/ϕ_E or u/u_E -- see Fig. B-2) for all the experimental runs are listed in Table B-5. The run identifications correspond to those in Table B-4.

Performance Measures

The open- and closed-loop parameters (Table B-4) extracted from the experimental data are based on the extended crossover model where the plant is assumed to be of the form

$$Y_pY_c\ (j\omega) = \frac{Ke^{-j(\tau_e\omega - \alpha/\omega)}}{j\omega}$$



in the region of crossover. A best "fit" to the describing function amplitude and phase data points for each run is made and the resulting plant and loop closure parameter extracted. These are identified in the table (and sketch) as follows:

HQR -- Cooper-Harper pilot rating given to configuration.

Kc -- Stick sensitivity (deg/s/inch for lateral and longitudinal commands and ft/s/inch for throttle commands).

EBAR -- average tracking error during the run (degrees of pitch and roll or ft/s of airspeed as appropriate)

ESIG -- one sigma rms value for tracking error during the run (degrees of pitch and roll or ft/s of airspeed tracking error as appropriate).

CSIG -- one sigma rms value for manipulator deflection during the run (inches of longitudinal or lateral stick or throttle as appropriate).

WC -- crossover frequency - frequency of crossover between open-loop 0 dB line and Bode amplitude asymptote calculated from a linear interpolation between the two describing function data points immediately above and below crossover (rad/s).

PML -- Bode open-loop phase margin at frequency of closed-loop gain crossover, ω_c; computed from a straight line interpolation between the two describing function data points immediately above and below ω_c (deg).

SLOPE -- slope of Bode open-loop amplitude asymptote between two data points immediately above and below gain crossover frequency (dB/decade).

TE -- plant open-loop high frequency time delay parameter from the exponential $\tau\omega$ (s).

ALPHA -- plant open-loop low frequency phase droop parameter from the exponential α/ω.

REFERENCE

B-1. McRuer, D. T., and E. S. Krendel, Mathematical Models of Human Pilot Behavior, AGARD-AG-188, Jan. 1974.

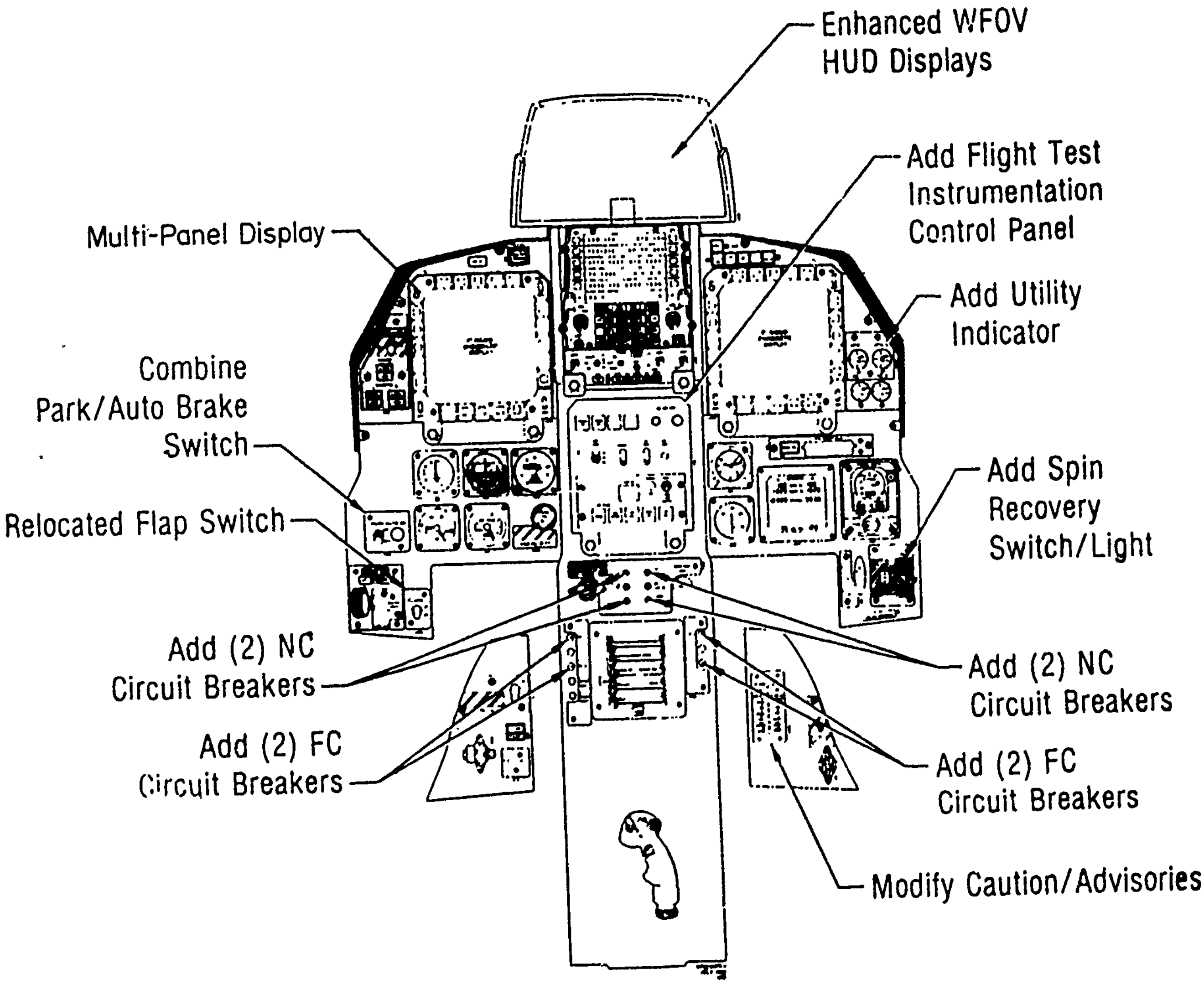


Figure B-1. Simulator Cockpit

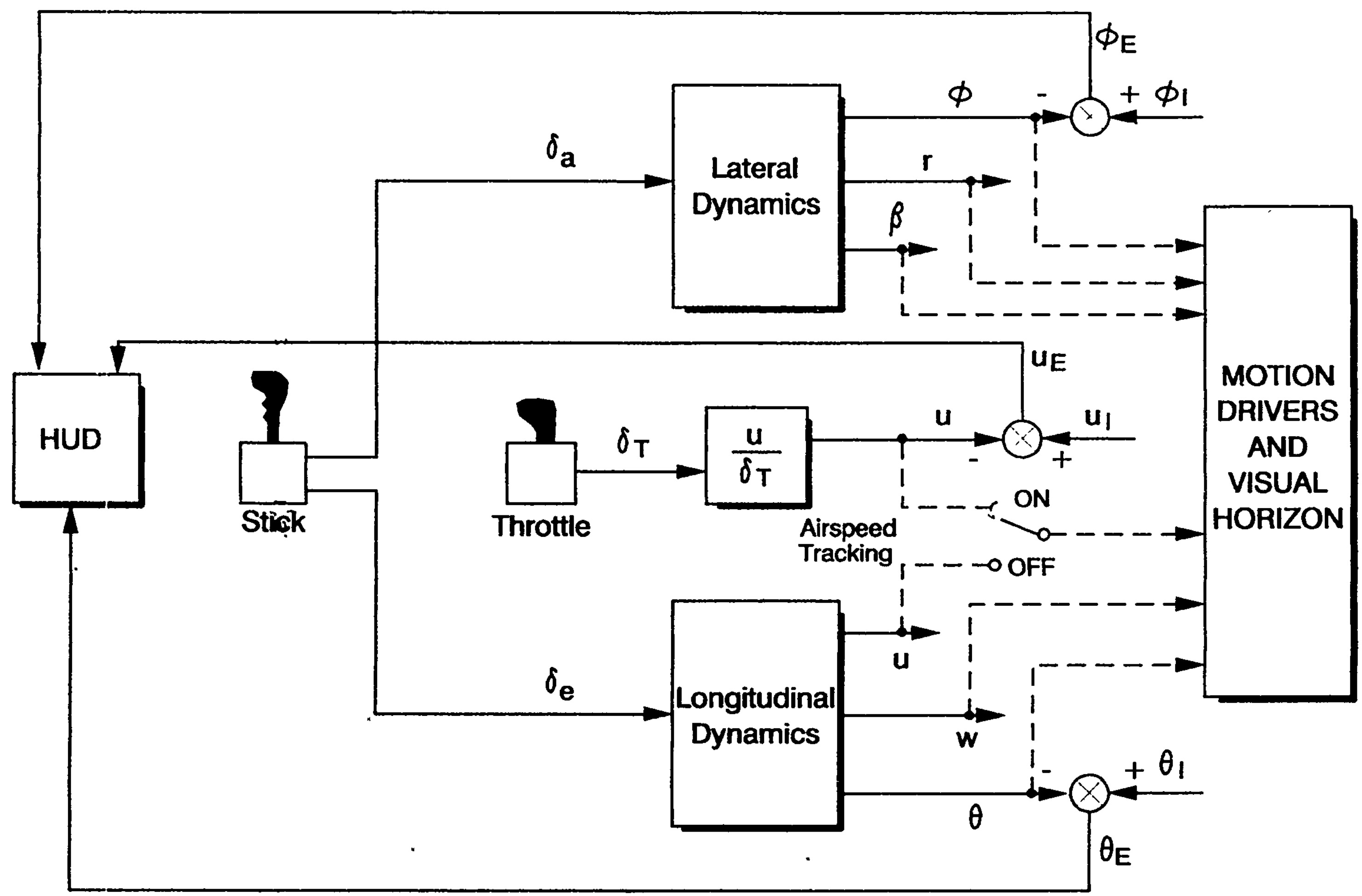


Figure B-2. HUD Tracking Task Setup on LAMARS

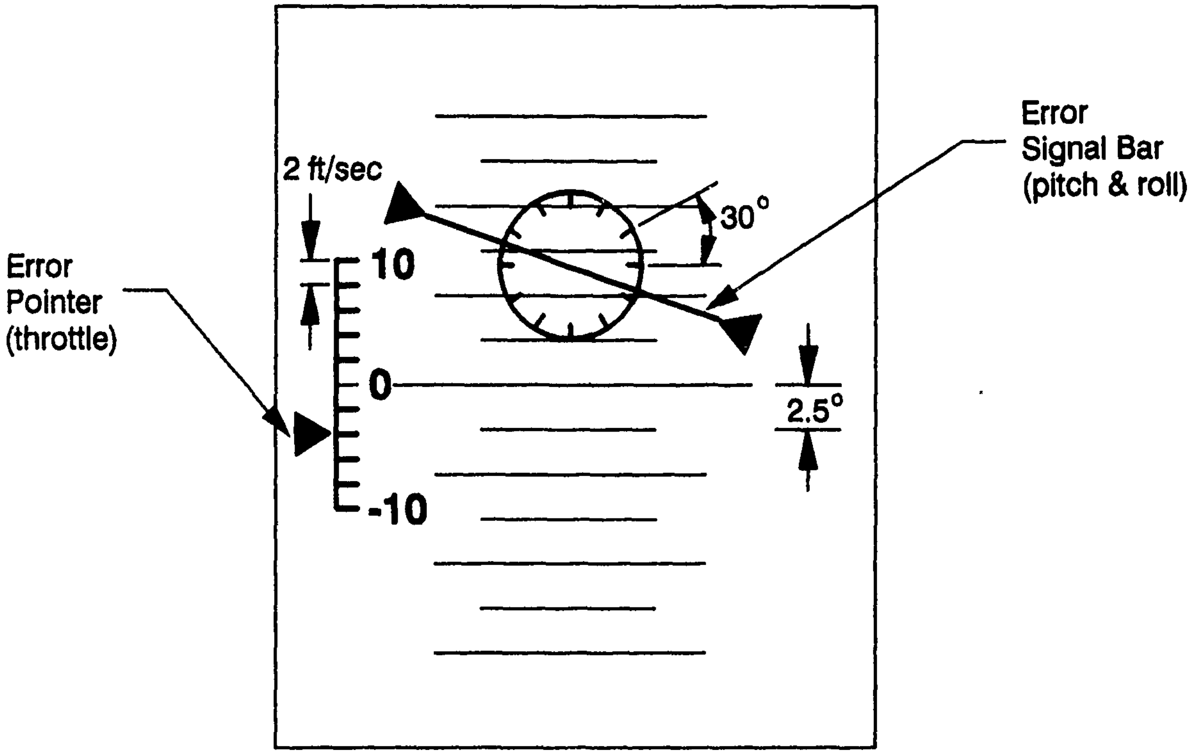


Figure B-3. Display for HUD Tracking Task

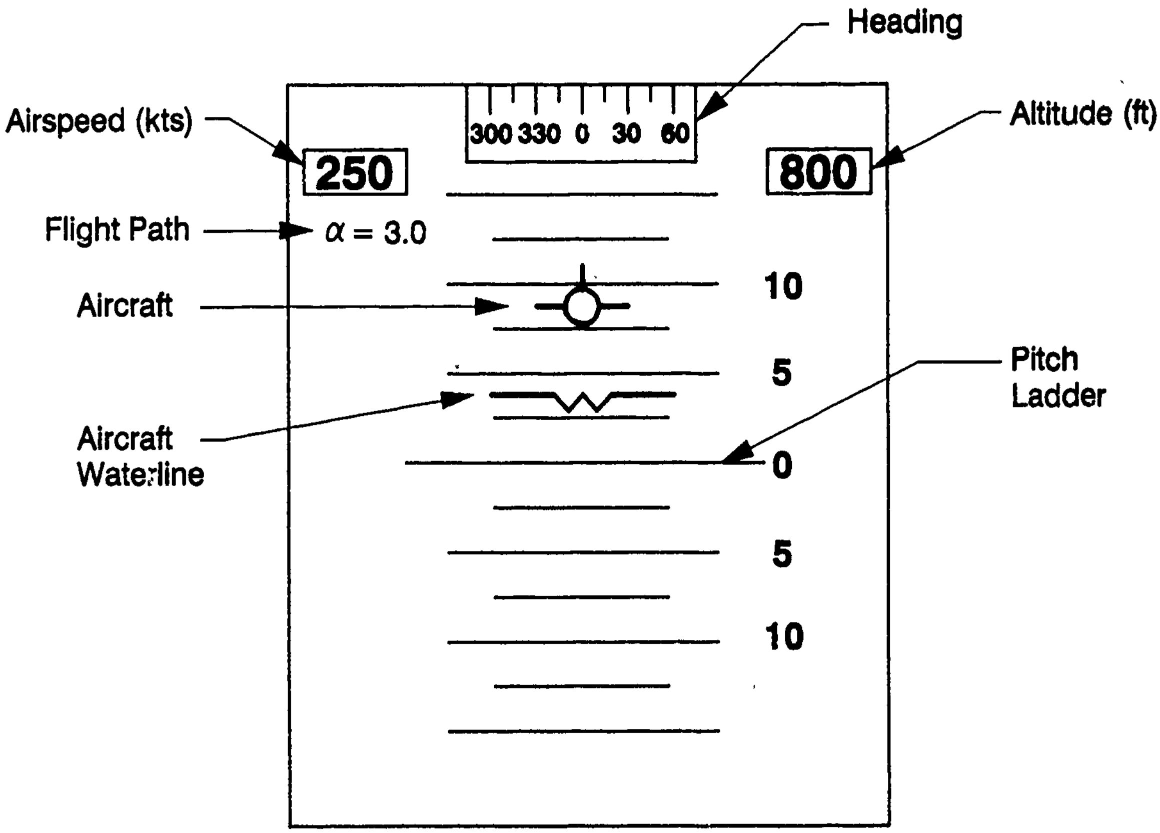


Figure B-4. Display for Visual Flight Task

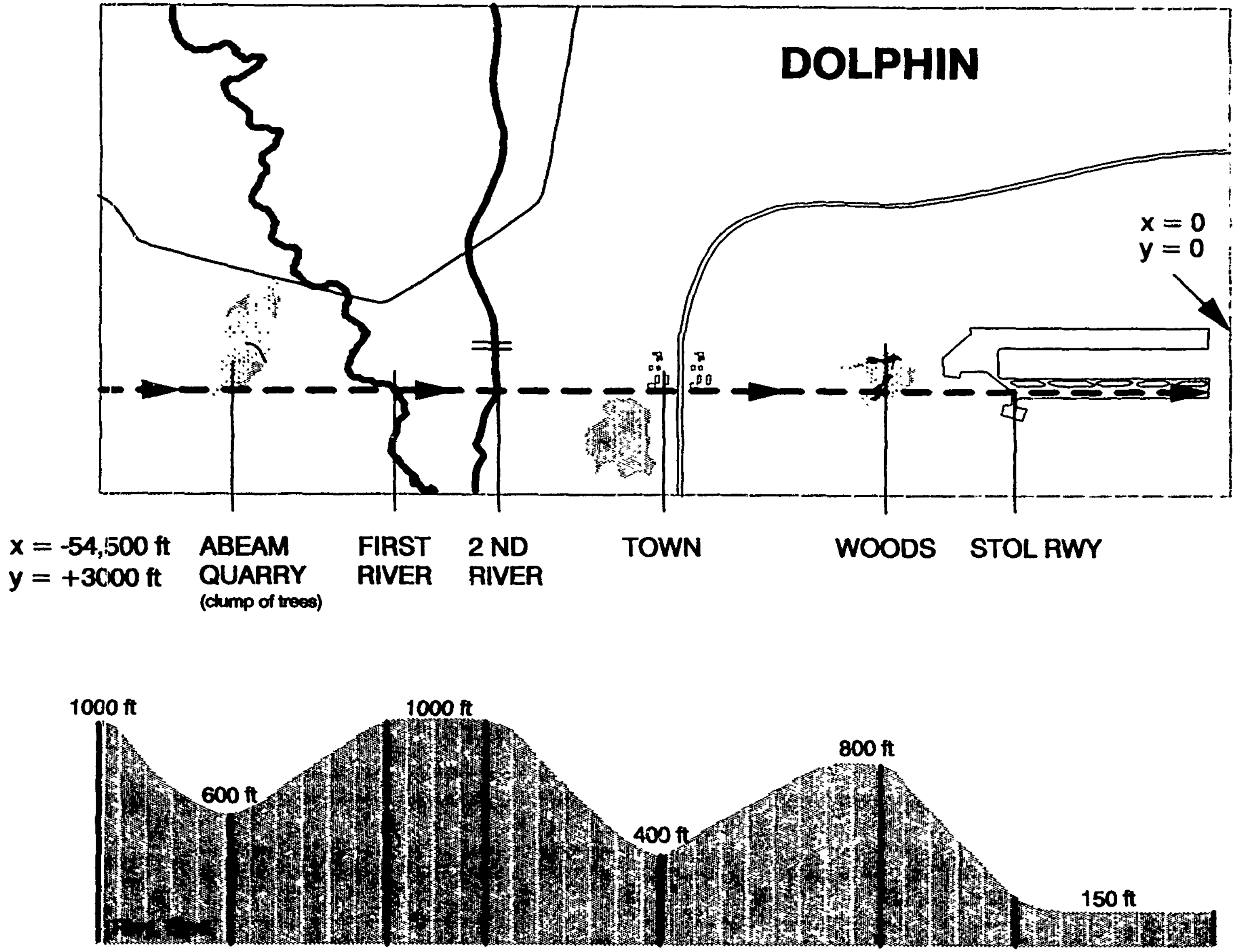


Figure B-5. Dolphin Task

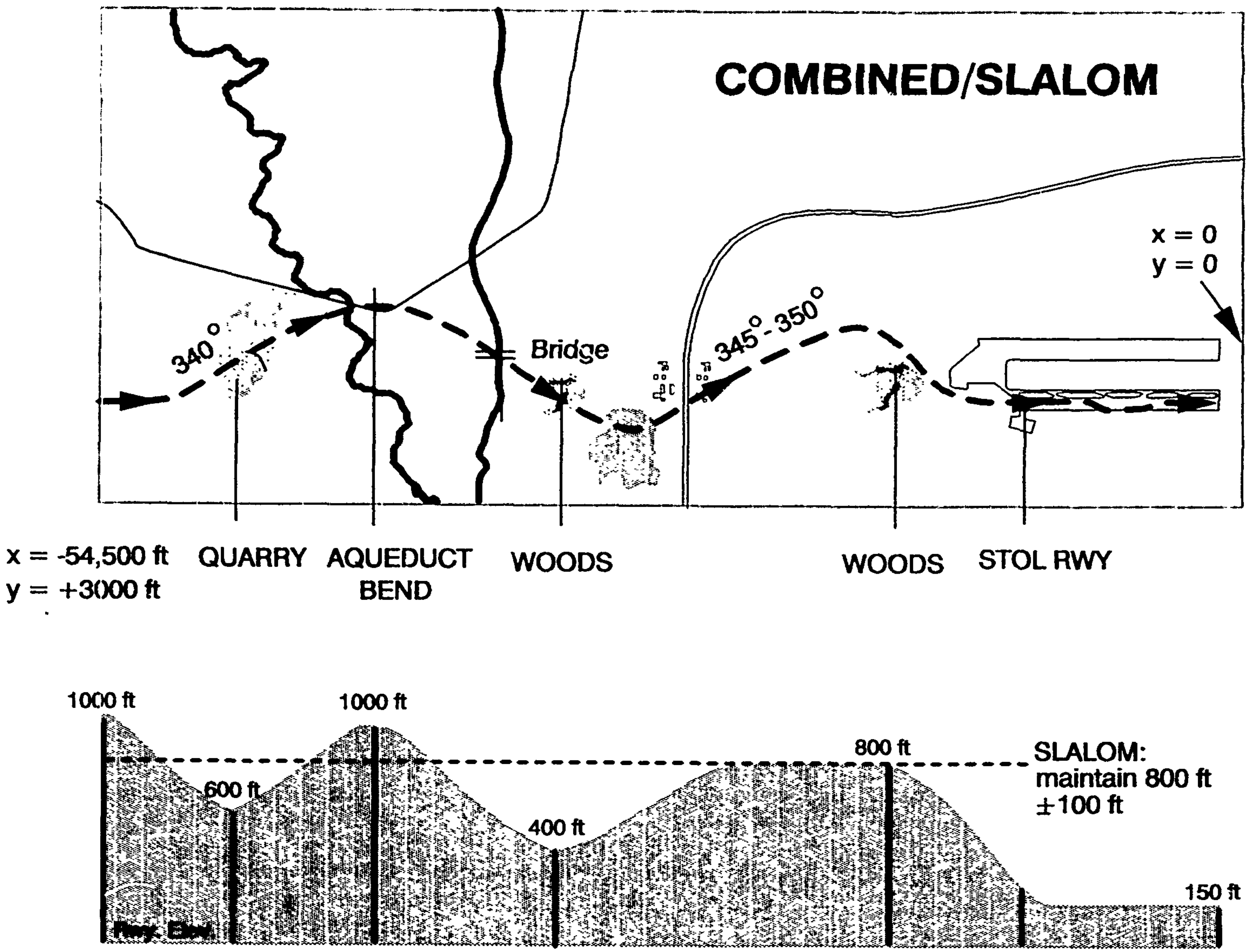
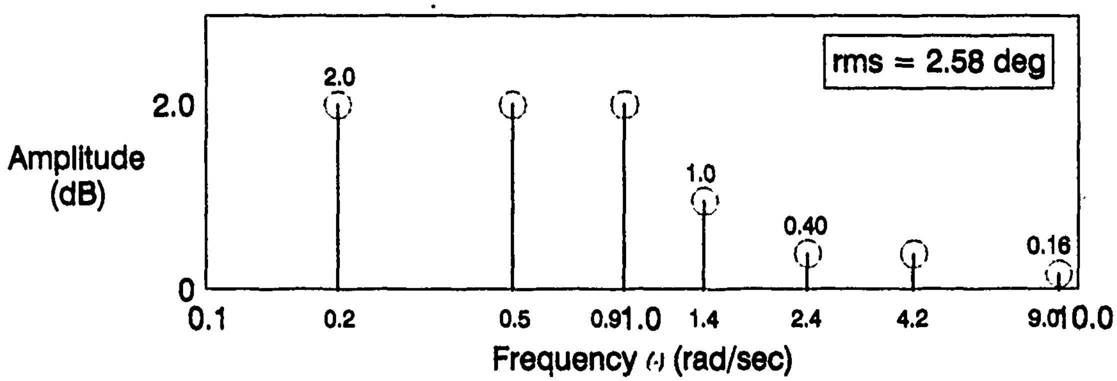
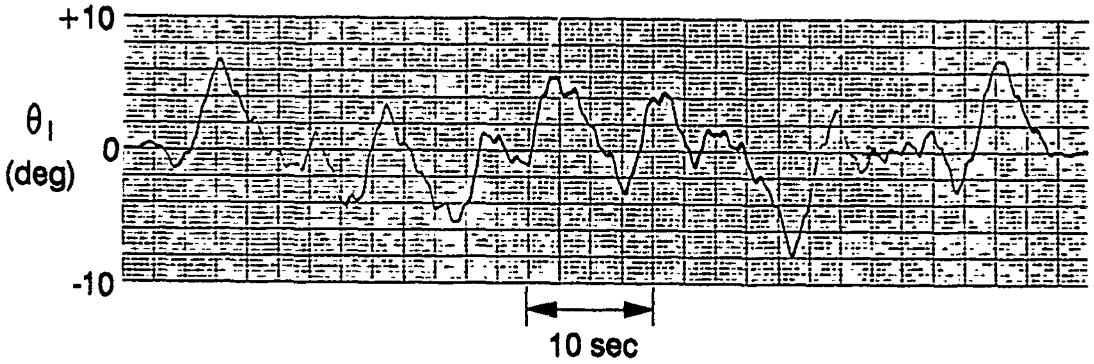


Figure B-6. Slalom and Combined-Axis Task

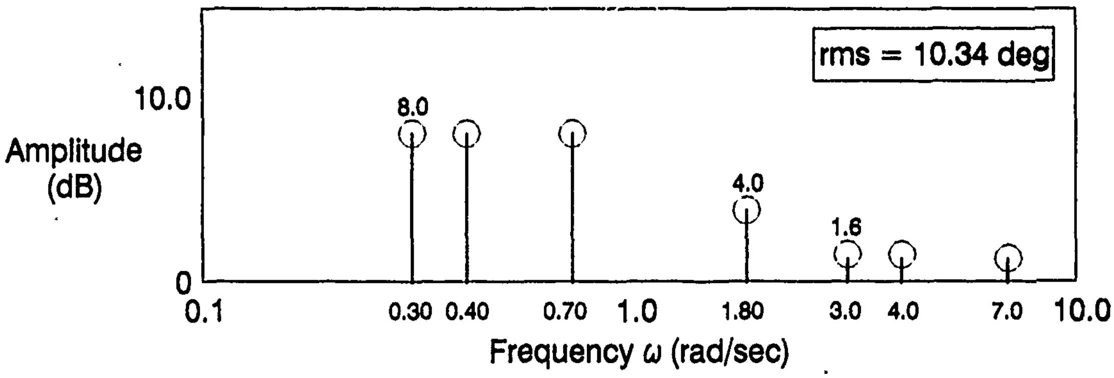


Signal Composition

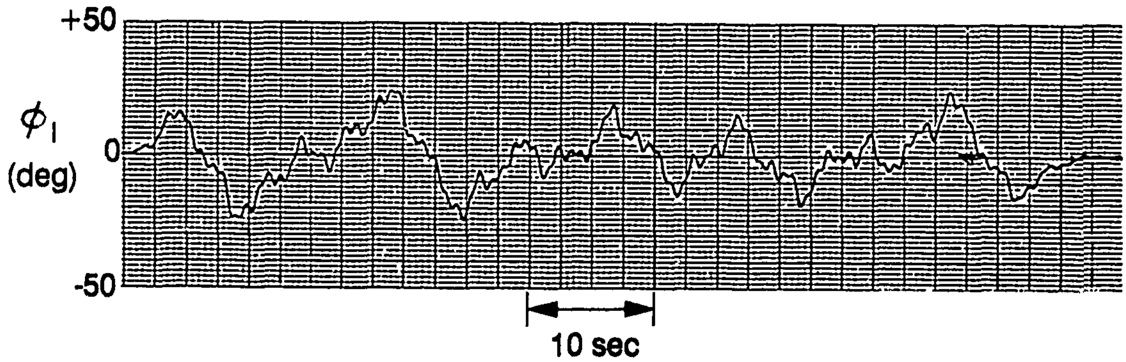


Time History (typical)

Figure B-7. Pitch Attitude Disturbance Function

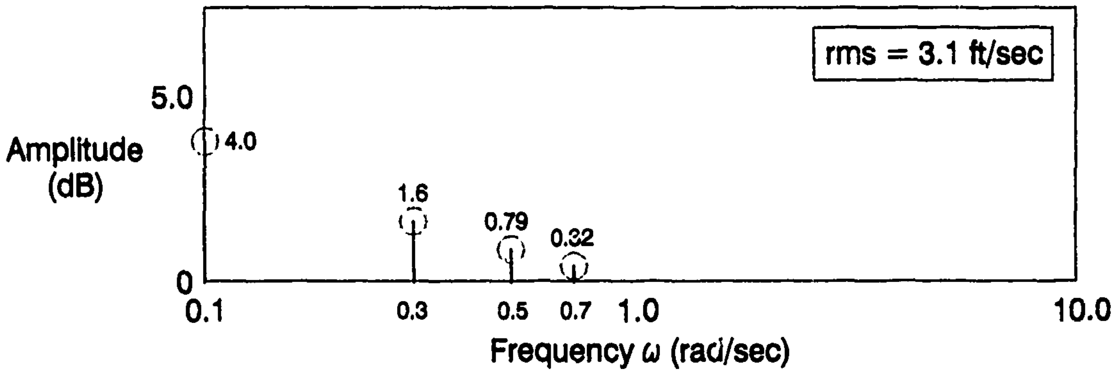


Signal Composition

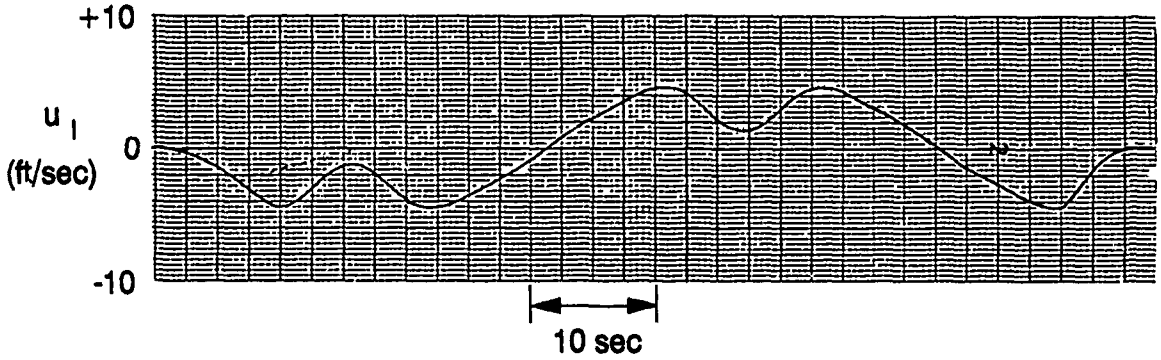


Time History (typical)

Figure B-8. Roll Attitude Disturbance Function

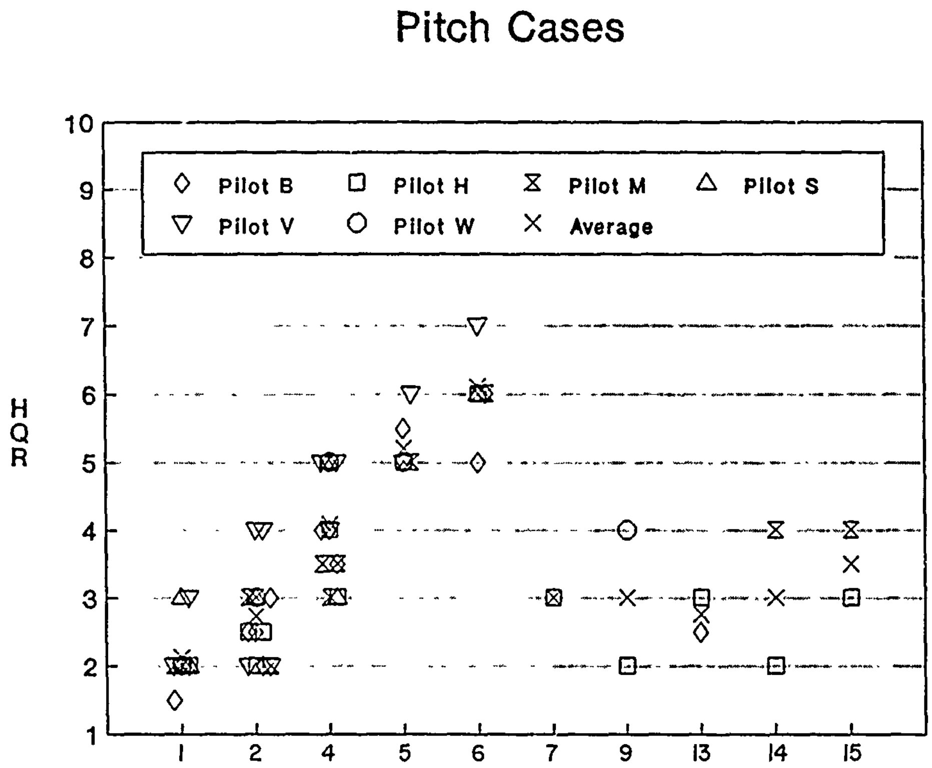


Signal Composition



Typical Time History

Figure B-9. Air Speed Disturbance Function



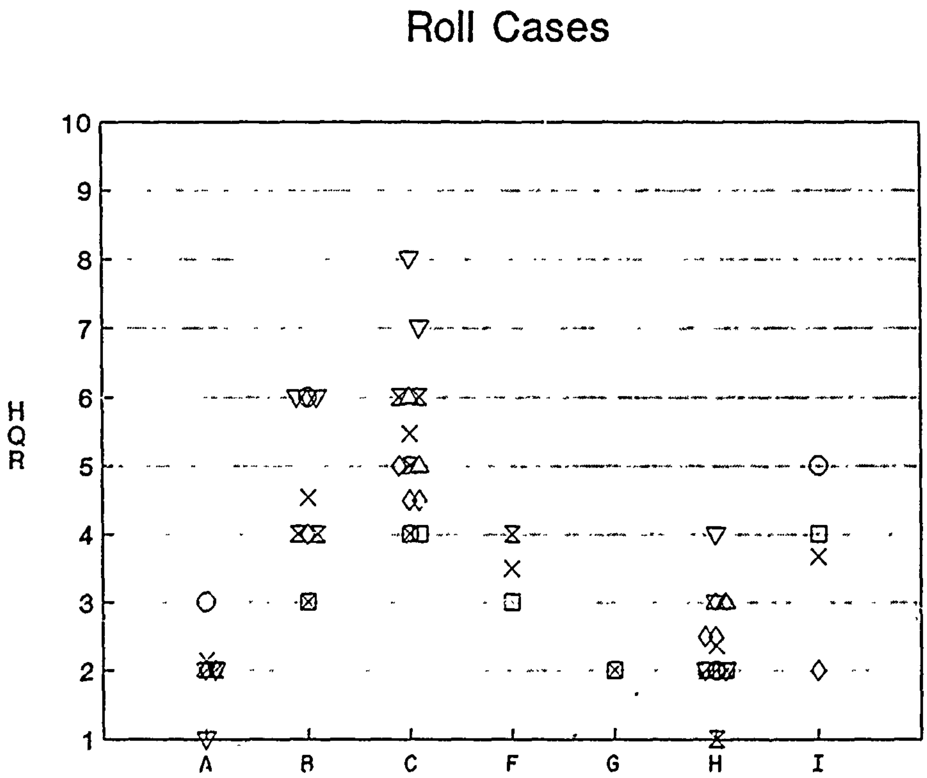
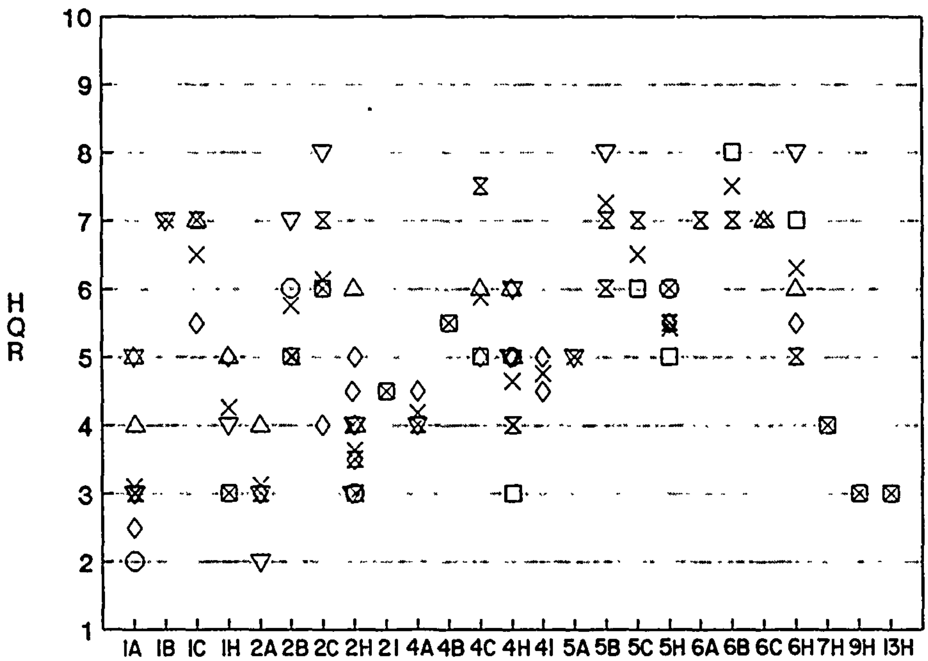


Figure B-10. Pilot Ratings (HUD Tracking)

Pitch/Roll Cases



Pitch/Throttle

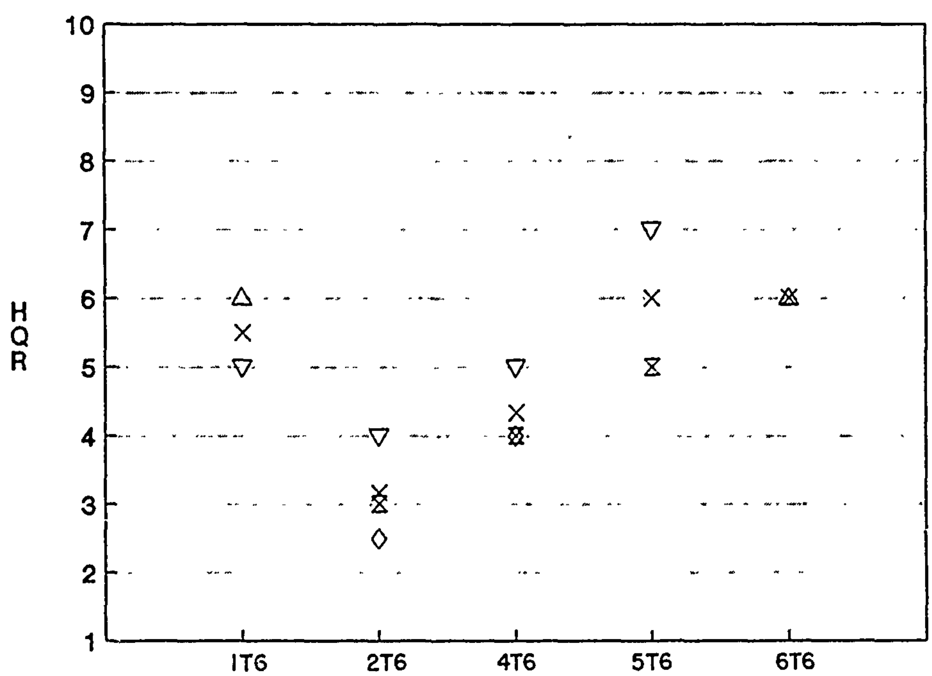
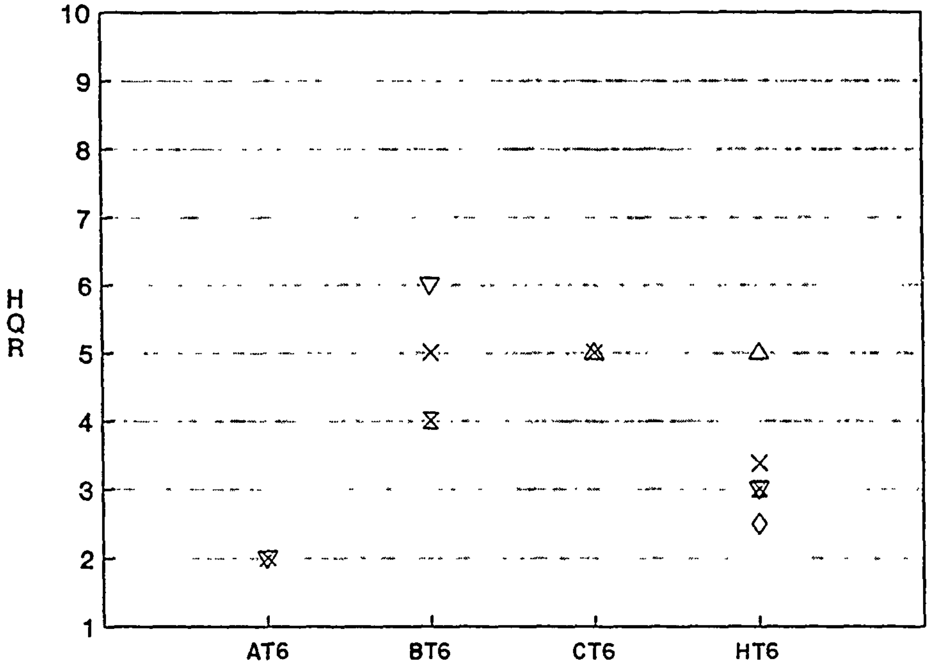


Figure B-10. (Continued)

Roll/Throttle



Pitch/Roll/Throttle

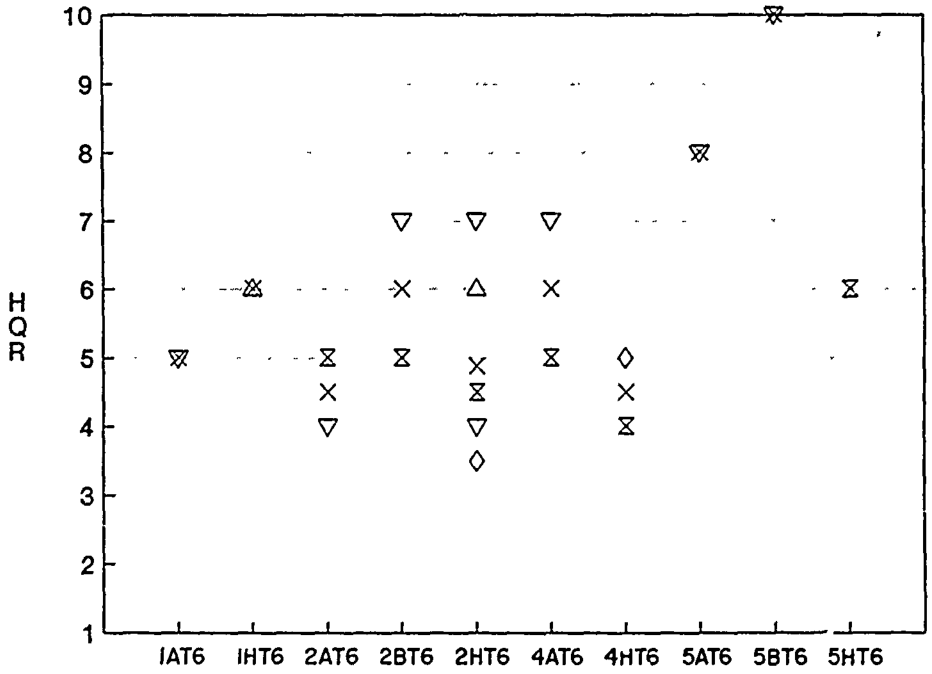


Figure B-10. (Concluded)

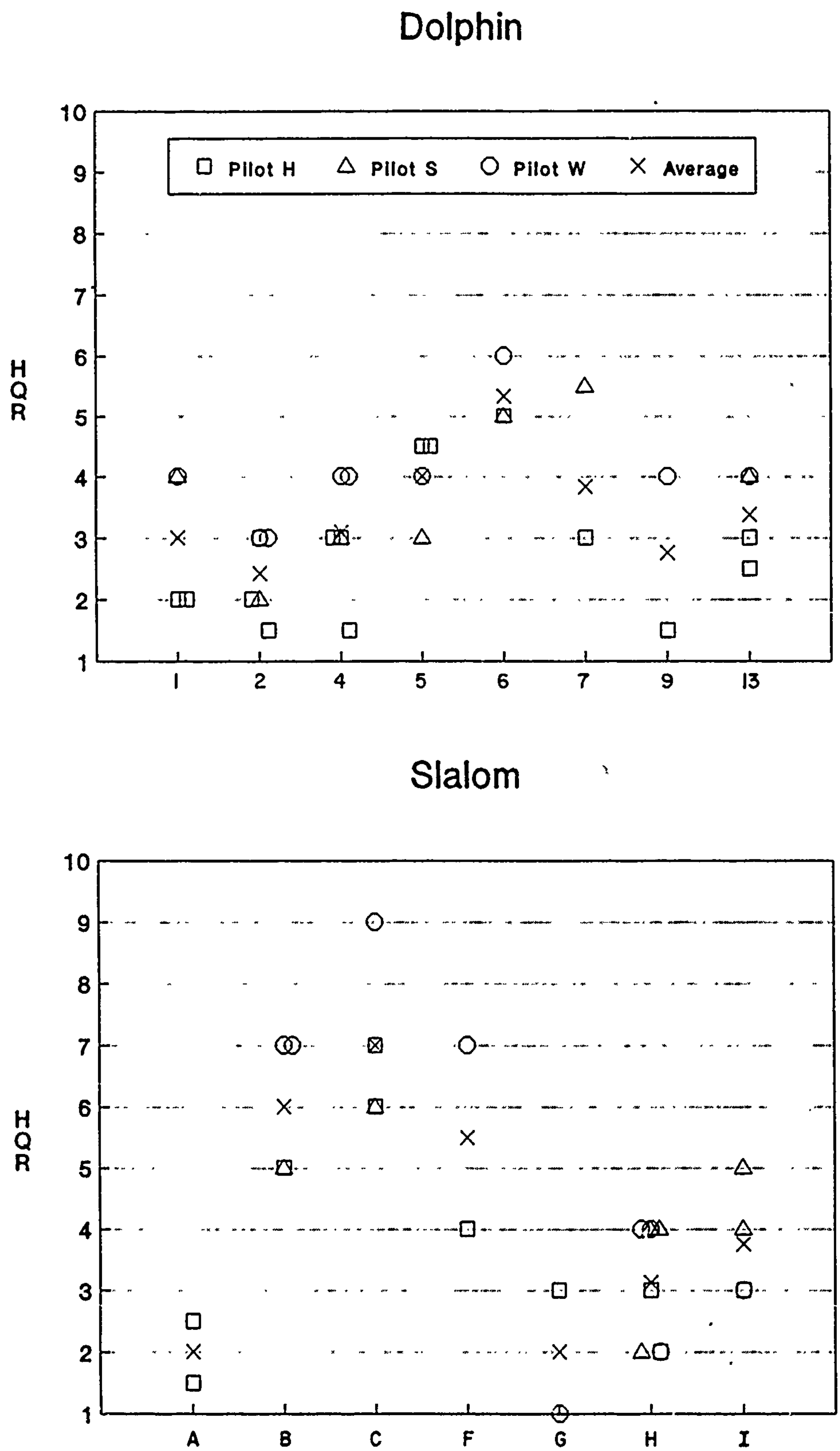


Figure B-11. Pilot Ratings (Visual Flight Task)

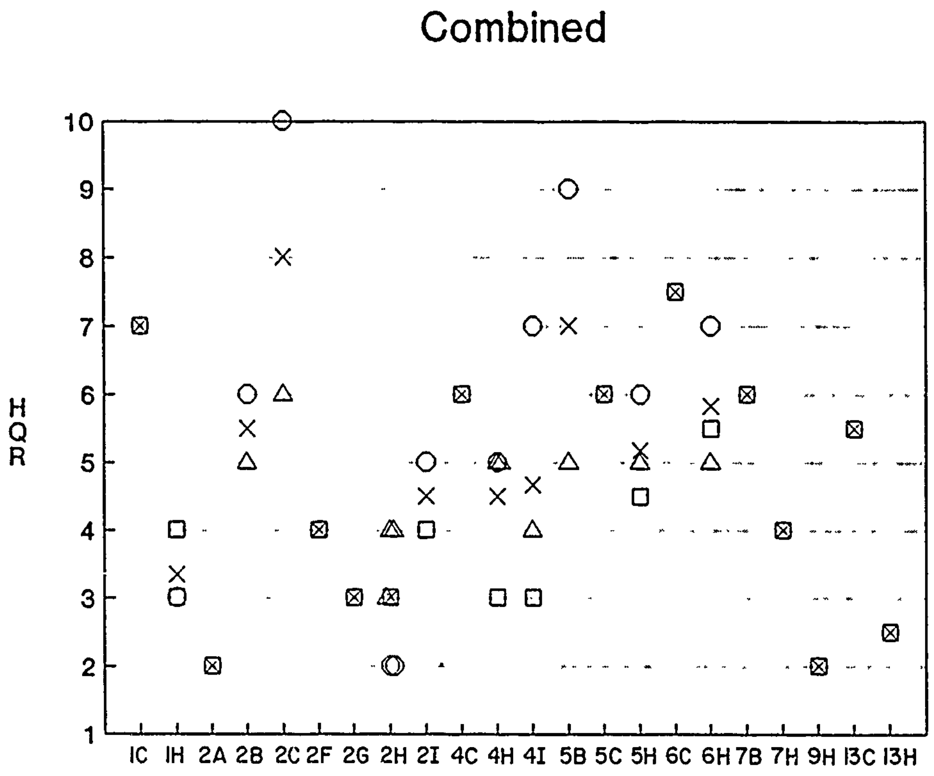


Figure B-11. (Concluded)

TABLE B-1. SIMULATED AIRCRAFT DYNAMICS

a. Longitudinal

LAMARS CASE	DENOMINATOR	NUMERATORS			
	Δ	$\frac{\theta}{\delta_e}$	$\frac{w}{\delta_e}$	$\frac{u}{\delta_e}$	$\frac{a_z}{\delta_e}$
1	(0)(0)(1.25)(100)	100(0)(1.25)	42200(0)(0)	.577(-6970)	-52700(0)(0)
2	(0)(0)[.8,5.0]	20(0)(1.25)	8440(0)(0)	.1154(-6970)	-10550(0)(0)
3	(0)(0)[.8,5.0]	20(0)(1.25){.067}	8440(0)(0){.067}	.1154(-6970){.067}	-10550(0)(0({.067}
4	(0)(0)[.8,5.0]	20(0)(1.25){.167}	8440(0)(0){.167}	.1154(-6970){.167}	-10550(0)(0({.167}
5	(0)(0)[.18,5.0]	20(0)(1.25)	8440(0)(0)	.1154(-6970)	-10550(0)(0)
6	(0)(0)[.18,5.0]	20(0)(1.25){.167}	8440(0)(0){.167}	.1154(-6970){.167}	-10550(0)(0({.167}
7	(0)(0)[.8,1.7]	2.31(0)(1.25)	975(0)(0)	.01334(-6970)	-1219(0)(0)
8	(0)(0)[.8,1.7]	2.31(0)(1.25){.167}	975(0)(0){.167}	.01334(-6970){.167}	-1219(0)(0({.167}
9	(0)(0)[.8,10]	80(0)(1.25)	33700(0)(0)	.461(6970)	-42200(0)(0)
10	(0)(0)[.63,.85]	1.445(0)(.5){.067}	609(0)(0){.067}	.00833(-2780){.067}	-304(0)(0){.067}
11	(0)(0)[.63,2.0]	8.0(0)(.5){.067}	3370(0)(0){.067}	.0461(-2780){.067}	-1688(0)(0){.067}
12	(0)(0)(0)(1.25)	(0)(1.25)	422(0)(0)	.00577(-6970)	-527(0)(0)
13	(0)(0)[.8,5.0](1.25)	50(0)(.5)(1.25)	368.24(0)(0)(.5)	-35.12(0.5)	-20732(.5)(0)(0)(1.27)
14	(0)(1.25)[.8,10]	100(0)(1.25)	42200(0)	-4025(1.25)	-52750(0)
15	(0)(1.25)[.8,10]	100(0)(1.25){.067}	42200(0){.087}	-4025(1.25){.087}	-52750(0){.087}
16	(0)(0)(.10)(-.80)	.1599(0)(.5){.067}	67.5(0)(0){.067}	.000923(-2780){.067	-33.7(0)(0){.067}

(a) = (s + a)
[ζ,ω] = $s^2 + 2\zeta\omega s + \omega^2$
{τ} = $e^{-\tau s}$

TABLE B-1. SIMULATED AIRCRAFT DYNAMICS (CONTINUED)

b. Lateral

LAMARS CASE	DENOMINATOR	NUMERATORS			
	Δ	$\frac{\phi}{\delta_a}$	$\frac{r}{\delta_a}$	$\frac{\beta}{\delta_a}$	$\frac{a_y}{\delta_a}$
A	(0)(100)[.4,2.0]	100[.4,2.0]	7.63[0.2]	.000331(36700)	−.000153(0)
B	(0)(.5)[.4,2.0]	.5[.4,2.0]{.034}	.0381[0,2]{.034}	.1657E-5(36800){.034}	−.765E-6(0){.034}
C	(0)(.5)[.4,2.0]	.5[.4,2.0]{.167}	.0381[0,2]{.167}	.1657E-5(36800){.167}	−.765E-6(0){.167}
D	(0)(1.25)[.4,2.0]	1.25[.4,2.0]{.015}	.0953[0,2]{.015}	.414E-5(36800){.015}	−.1913E-5(0){.015}
E	(0)(2.22)[.4,2.0]	2.22[.4,2.0]{.015}	.1693[0,2]{.015}	.736E-5(36800){.015}	−.339E-5(0){.015}
F	(0)(2.22)[.4,2.0]	2.22[.4,2.0]{.14}	.1693[0,2]{.14}	.736E-5(36800){.14}	−.339E-5(0){.14}
G	(0)(2.22)(6)[.4,2.0]	13.32[.4,2.0]	1.016[0,2]	4.416E-5(36800)	−2.034E-5(0)
H	(0)(4)[.4,2.0]	4.0[.4,2.0]{.034}	.305[0,2]{.034}	.1326E-4(36800){.034}	−.612E-5(0){.034}
I	(0)(4)[.4,2.0]	4.0[.4,2.0]{.167}	.305[0,2]{.167}	.1326E-4(36800){.167}	−.612E-5(0){.167}
J	(0)(6.67)[.4,2.0]	6.67[.4,2.0]{.015}	.508[0,2]{.015}	.221E-4(36800){.015}	−.1020E-4(0){.015}
K	(0)(6.67)[.4,2.0]	6.67[.4,2.0]{.09}	.508[0,2]{.09}	.221E-4(36800){.09}	−.1020E-4(0){.09}
L	(0)(6.67)[.4,2.0](10)	66.7[.4,2.0]	5.08[0,2]	2.21E-4(36800)	−1.020E-4(0)

$(a) \equiv (s + a)$
$[\zeta,\omega] \equiv s^2 + 2\zeta\omega s + \omega^2$
$\{\tau\} \equiv e^{-\tau s}$

TABLE B-1. SIMULATED AIRCRAFT DYNAMICS (CONCLUDED)

c) Airspeed-to-Throttle

LAMARS CASE	$Y_c = \frac{u}{\delta_T}$
T1	$\frac{1}{(10)}$
T2	$\frac{1}{(.2)}$
T3	$\frac{1}{(0)(.5)}$
T4	$\frac{1}{(0)(1.0)}$
T5	$\frac{1}{(0)(2.0)}$
T6	$\frac{1}{(0)(10)}$

$(a) \equiv (s + a)$

TABLE B-2. TABLE OF CONFIGURATIONS FOR LAMARS SIMULATION

a) Longitudinal

LAMARS CASE	θ/δ_e
1	k/s
2	$\dfrac{(1.25)\{0.033\}}{(0)[0.8,5.0]}$
3	$\dfrac{(1.25)\{0.100\}}{(0)[0.8,5.0]}$
4	$\dfrac{(1.25)\{0.200\}}{(0)[0.8,5.0]}$
5	$\dfrac{(1.25)\{0.033\}}{(0)[0.18,5.0]}$
6	$\dfrac{(1.25)\{0.200\}}{(0)[0.18,5.0]}$
7	$\dfrac{(1.25)\{0.033\}}{(0)[0.8,1.7]}$
8	$\dfrac{(1.25)\{0.200\}}{(0)[0.8,1.7]}$
9	$\dfrac{(1.25)\{0.033\}}{(0)[0.8,10.0]}$
10	$\dfrac{(0.5)\{0.100\}}{(0)[0.63,0.85]}$
11	$\dfrac{(0.5)\{0.100\}}{(0)[0.63,2.0]}$

TABLE B-2. (Continued)

a) Longitudinal

LAMARS CASE	θ/δ_e
12	k/s^2
13	$\dfrac{(0.5)\{0.033\}}{(0)[0.8,5.0]}$
14	$\dfrac{\{0.033\}}{[0.8,10.0]}$
15	$\dfrac{\{0.12\}}{[0.8,10.0]}$
16	$\dfrac{(0.5)\{0.100\}}{(0)(0.1)(-0.8)}$

TABLE B-2. (Continued)

b) Lateral

LAMARS CASE	ϕ/δ_a
A	k/s
B	$\frac{\{0.067\}}{(0)(0.5)}$
C	$\frac{\{0.200\}}{(0)(0.5)}$
D	$\frac{\{0.048\}}{(0)(1.25)}$
E	$\frac{\{0.048\}}{(0)(2.22)}$
F	$\frac{\{0.173\}}{(0)(2.22)}$
G	$\frac{\{0.023\}}{(0)(2.22)(6)}$
H	$\frac{\{0.067\}}{(0)(4.0)}$
I	$\frac{\{0.200\}}{(0)(4.0)}$
J	$\frac{\{0.048\}}{(0)(6.67)}$
K	$\frac{\{0.123\}}{(0)(6.67)}$

TABLE B-2. (CONCLUDED)

b) Lateral

LAMARS CASE	ϕ/δ_a
L	$\frac{(0.023)}{(0)(6.67)(10)}$

c) Speed Axis

LAMARS CASE	u/δ_T
T1	$\frac{(0.033)}{(10)}$
T2	$\frac{(0.033)}{(0.2)}$
T3	$\frac{(0.033)}{(0)(0.5)}$
T4	$\frac{(0.033)}{(0)(1.0)}$
T5	$\frac{(0.033)}{(0)(2.0)}$
T6	$\frac{(0.033)}{(0)(10.0)}$

TABLE B-3. RUN LOG FOR LAMARS SIMULATION

RUN NO.	DFA RUN NO.	PILOT	CONF.	HQR	COMMENTS
14-15	14FEB89.AN-AO	M	1	2	S.O.S.; Fixed Base; All Roll
16-17	.AP-AQ		4	4	Runs have High Forcing
18-19	.AR-AS		6	6-1/2	Function Amplitude
20-21	.AT-AU		A	4	
22-23	.AV-AW		H	4	
24-25	.AX-AY		C	5-1/2	
26-27	.AZ-BA		4 T6	4	
28-29	.BB-BC		1A	4	
30-31	.BD-BE		4H	5	
32-33	.BF-BG		6C	7	
34	.BH		4HT6	4	-No S.O.S. to Throttle
35-36	.BI-BJ		4HT6	4-1/2	
37-39	.BK-BM	M	1	2-1/2	S.O.S.; Motion Base
40-41	.BN-BO		2	3	
42-43	.BP-BQ		4	4	
44-45	.BR-BS		6	6	
46-48	.BT-BV		H	2	-Roll F.F. Amplitude Reduced
49-50	.BW-BX		C	4-1/2	
51-52	15FEB89.AK-AL	M	1	2	
53-54	.AM-AN		H	3	
55	.AO		T6	1	
56-57	.DA		1H	3	-No DFA for Run 56
58-59	.DB-DC		4H	5	
60-61	.DD-DE		4C	5-1/2	
62-63	.DF-DG		4HT6	6	
64-65	15FEB89.DH-DI	V	1	4*	
66-67	.DJ-DK		2	4	
68-69	.DL-DM		4	5	
70-71	.DN-DO		1	2	
72-73	.DP-DQ		6	7	
74-75	.DR-DS		A	2	
76-77	.DT-DU		H	4	
78-79	.DV-DW		C	8	
80-81	.DX		T6	–	-Practice; No DFA for Run 80
82-84	.DY-EA		1A	5	
85-88	.EB-EE		1H	4	
89-90	.EF-EG		2H	4	
91-93	.EH-EJ		4H	5	
94-95	.EK-EL		1A	3	
96-97	16FEB89.AS-AT	S	1	3	S.O.S.
98-99	.AU-AV		2	3	
100-102	.AW-AY		4	5	
103-104	.AZ-BA		H	3	

*First Runs for Pilot V; Low Crossover - Not used in Analysis

TABLE B-3. RUN LOG FOR LAMARS SIMULATION (CONTINUED)

RUN NO.	DFA RUN NO.	PILOT	CONF.	HQR	COMMENTS
105-106	16FEB89.BB-BC	S	A	2	
107-108	.BD-BE		C	6	
109-111	.BF-BH		1A	5	
112-114	.BI-BK		2A	4	
115-117	.BL-BN		2H	6	
118-119	.BO-BP		4H	6	
120-121	.BQ-BR		1C	7	
122-124	.BS-BU		1A	4	
125-126	.BV-BW		4C	6	
127-129	.BX-BZ		2H	4	
130	.CA		T6	1	
131-133	.CB-CD		2HT6	6	
134-136	17FEB89.AB-AC	B	1	2	-No DFA for Run 134
137-138	.AD-AE		2	2-1/2	
139-140	.AF-AG		4	4	
141-142	.AH-AI		2	2	
143-145	.AJ-AL		6	5	
146-147	.AM-AN		A	2	
148-149	.AO-AP		H	2-1/2	
150-153	.AQ-AT		C	4-1/2	
154-156	.AU-AW		1A	2-1/2	
157-159	.AX-AZ		4H	5	
160-161	.BA-BB		2H	3-1/2	
162-165	.BC-BF		2C	4	
166-170	.BG-BK		6H	5 1/2	
171-173	.BL-BN		4C	5	
174-175	21FEB89.AB-AC	M	1	2	
176-177	.AD-AE		2	3	
178-180	.AF-AH		4	3	
181-182	.AI-AJ		5	5	
183-184	.AK-AL		4	3	
185-187	.AM-AO		6	6	
188-189	.AP-AQ		A	2	
190-191	.AR-AS		H	2	
192-193	.AT-AU		C	5	
194-195	.AV-AW		1A	3	
196-197	.AX-AY		2H	3-1/2	
198-199	.AZ-BA		2C	6	
200-201	.BB-BC		4H	4	
202	21FEB89.BE	V	1	3	S.O.S.
203-204	.BF-BG		4	5	
205-207	.BH-BJ		H	2	
208-209	.BK-BL		C	7	
210-211	.BM-BN		1A	3	
212-213	.BO-BP		4H	6	
214-215	.BQ-BR		2H	4	
216-217	.BS-BT		2C	8	
218-219	.BU-BV		4H	5	

TABLE B-3. RUN LOG FOR LAMARS SIMULATION (CONTINUED)

RUN NO.	DFA RUN NO.	PILOT	CONF.	HQR	COMMENTS
220-221	21FEB89.BW-BX	V	1A	3	
222-223	.BZ-CA		6H	8	
224-225	.CB-CC		2C	8	
226	.CD		T6	3	
227-228	.CE-CF		1AT6	5	
229-230	.CG-CH		2HT6	7	
231-232	22FEB89.AJ-AK	V	1	2	
233-234	.AL-AM		2	4	
235-236	.AN-AO		4	5	
237-238	.AP-AQ		H	2	
239-240	.AR-AS		B	6	
241-242	.AT-AU		2H	3	
243-244	.AW-AX		4A	4	
245-246	.AY-AZ		1B	7	
247-248	.BA-BB		4AT6	7	
249-250	22FEB89.CA-CB	M	2	2	
251-252	.CC-CD		4	3-1/2	
253-254	.CE-CF		A	2	
255-256	.CG-CH		C	6	
257-258	.CI-CJ		2A	3	
259-260	.CK-CL		4A	4	
261-262	.CM-CN		1C	7	
263-264	.CO-CP		4C	7-1/2	
265-266	.CQ-CR		6A	7	
267-268	.CS-CT		2AT6	5	
269-270	.CU-CV		4AT6	5	
271-272	22FEB89.CW-CX	V	2A	2	
273-274	.CY-CZ		2AT6	4	
275-292	———		-	———	Prelim. Evals. of Ldg Approach Task (Later Dropped) - Data not used in Analysis
293-294	23FEB89.AA-AB	V	2	2	S.O.S.
295-296	.AC-AD		5	5	
297-298	.AE-AF		A	2	
299-300	.AG-AH		B	6	
301-302	.AI-AJ		2B	7	
303-304	.AK-AL		2 T6	4	
305-306	.AM-AN		5 T6	7	
307-308	23FEB89.BA-BB	S	1	2	
309-310	.BC-BD		4	[illegible]	
311-312	.BE-BF		6	6	
313-314	.BG-BH		H	3	
315-316	.BI-BJ		C	5	
317-319	.BK-BM		1H	5	
320-321	.BN-BO		6H	6	
322-324	.BP-BR		4H	5	
325-326	.BS-BT		6C	7	
326A	.BU		T6	4	

TABLE B-3. RUN LOG FOR LAMARS SIMULATION (CONTINUED)

RUN NO.	DFA RUN NO.	PILOT	CONF.	HQR	COMMENTS
327-328	23FEB89.BV-BW	S	1 T6	6	
329-330	.BX-BY		6 T6	6	
331-332	.BZ-CA		HT6	5	
333-334	.CB-CC		CT6	5	
335-336	.CD-CE		1HT6	6	
337-340	——		—	—	See comments for Runs 275-292
341-342	24FEB89.AA-AB	B	1	2	
343-344	.AC-AD		2	3	
345-346	.AE-AF		4	3-1/2	
347-348	.AG-AH		A	2	
349-350	.AI-AJ		C	4-1/2	
351-352	.AK-AL		H	3	
353-354	.AM-AN		2A	3	
355-357	.AO-AQ		1C	5-1/2	
358-360	.AR-AT		4A	4-1/2	
361-362	.AU-AV		1H	5	
363-380	——		—	—	See comments for Runs 275-292
381-383	——	V	2	2	-No DFA for Runs 381-383
384-385	24FEB89.DA-DB		4	4	
386-387	.DC-DD		5	6	
388-389	.DE-DF		A	1	
390-391	.DG-DH		H	3	
392-393	.DI-DJ		B	6	
394-395	.DK-DL		2A	3	
396-397	.DM-DN		5A	5	
398-399	.DO-DP		5B	8	
400	.DQ		T6	1	
401-403	.DR-DT		1 T6	5	
404-405	.DU-DV		4 T6	5	
406-407	.DW-DX		AT6	2	
408-409	.DY-DZ		BT6	6	
410-411	.EA		HT6	3	-No DFA for Run 410
412-413	.EB-EC		2BT6	7	
414-415	.ED-EE		5AT6	8	
416-417	.EF-EG		2HT6	4	
418-419	.EH-EI		5BT6	10	
420-429	——		—	—	See comments for Runs 275-292
430-431	13MAR89.AA-AB	M	1	2	
432-433	.AC-AD		2	3	
434-435	.AE		5	5	-No DFA for Run 434
436-438	.AF-AH		4	3-1/2	
439-440	.AI-AJ		6	6	
441-442	.AK-AL		H	2	
443-444	.AM-AN		B	3	
445-446	.AO-AP		C	6	
447-448	.AQ-AR		1	2	
449-451	.AS-AU		14	4	
452-453	.AV-AW		15	4	

TABLE B-3. RUN LOG FOR LAMARS SIMULATION (CONTINUED)

RUN NO.	DFA RUN NO.	PILOT	CONF.	HQR	COMMENTS
454-455	13MAR89.AX-AY	M	H	1	
456-457	.AZ-BA		B	4	
458-459	.BB-BC		F	4	
460-461	.BD-BE		G	2	
462-464	.BF-BH		1A	3	
465-466	.BI-BJ		2H	3	
467-468	.BK-BL		2B	5	
469-470	.BM-BN		2H	2	-No Pitch F.F. - Pitch Free
471-472	.BO-BP		2C	7	
473-475	.BQ-BS		5H	6	
476-477	.BT-BU		5B	6	
478-479	.BV-BW		5H	5	-No Roll F.F. - Roll Free
480-481	.BX-BY		5C	7	
482-485	.BZ-CC		6H	5	
486-487	.CD-CE		6B	7	
488-489	.CF-CG		4H	4	
490-491	14MAR89.AE-AF	M	2	2	S.O.S.
492-493	.AG-AH		5	5	
494-495	.AI-AJ		4	4	
496-497	.AK-AL		H	2	
498-499	.AM-AN		B	4	
500-501	.AO-AP		T1	2	
502	.AQ		T2	1	
503	.AR		T6	1	
504-506	.AS-AU		2H	4	
507-508	.AV-AW		2B	5	
509-510	.AX-AY		5H	5-1/2	
511-512	.AZ-BA		5B	7	
513-515	.BB-BD		2 T1	3	
516-517	.BE-BF		4 T1	4	
518-519	.BG-BH		2 T6	3	
520-521	.BI-BJ		5 T1	5	
522-523	.BK-BL		2 T2	3	
524-525	.BM-BN		5 T2	5	
526-527	.BO-BP		5 T6	5	
528-529	.BQ-BR		HT2	4	
530-531	.BS-BT		BT1	4	
532-533	.BU-BV		BT6	4	
534-535	.BW-BX		HT1	3	
536-537	.BY-BZ		BT2	4	
538-540	.CA-CC		2HT1	4-1/2	
541-542	.CD-CE		2HT6	4-1/2	
543-544	.CF-CG		2BT1	6	
545-546	.CH-CI		4HT1	4	
547-548	.CJ-CK		2BT6	5	
549-551	.CL-CN		5HT6	6	
552-554	.CO-CQ		5HT1	6	

TABLE B-3. RUN LOG FOR LAMARS SIMULATION (CONTINUED)

RUN NO.	DFA RUN NO.	PILOT	CONF.	HQR	COMMENTS
555-556	15MAR89.AA-AB	H	1	2	S.O.S.
557-558	.AC-AD		2	2	
559-561	.AE-AG		4	4	
562-563	.AH-AI		6	6	
564-565	.AJ-AK		H	2	
566-567	.AL-AM		B	3	
568-569	.AN-AO		C	4	
570-571	.AP-AQ		2H	3	
572-573	.AR-AS		2B	5	
574-575	.AT-AU		4H	3	
576-577	.AV-AW		6H	7	
578-579	.AX-AY		4B	5-1/2	
580-581	.AZ-BA		4H	3	
582	——	H	2H	3	Combined-Axis Task
583-584			4H	3	
585-586			6H	5-1/2	
587-588			2H	3	Dolphin
589-590			4A	3	
591-592			6A	5	
593-595			1H	3	Slalom
596-598			1B	5	
599-600			1C	7	
601-602	15MAR89.BB-BC	H	2	2-1/2	S.O.S.
603-604	.BD-BE		14	2	
605-606	.BF-BG		15	3	
607-608	.BH-BI		2C	6	
609-610	.BJ-BK		6B	8	
611-612	——		1A	2	Dolphin
613-614			5A	4-1/2	
615-616			1A	2-1/2	Slalom
617-618	16MAR89.AA-AB	H	1	2	S.O.S.
619-620	.AC-AD		4	3	
621-622	.AE-AF		5	5	
623-624	.AG-AH		H	2	
625-626	.AI-AJ		F	3	
627-628	.AK-AL		C	4	
629-630	.AM-AN		G	2	
631-632	.AO-AP		1H	3	
633-634	.AQ-AR		4C	5	
635-636	.AS-AT		5H	5	
637-638	.AU-AV		5C	6	
639-640	——	H	1A	2	Dolphin
641-642			5A	4-1/2	
643-644			4A	1-1/2	
645-646			1H	2	Slalom
647-648			1C	6	
649-650			1F	4	

TABLE B-3. RUN LOG FOR LAMARS SIMULATION (CONTINUED)

RUN NO.	DFA RUN NO.	PILOT	CONF.	HQR	COMMENTS
651-652	16MAR89.AW-AX	H	2	2-1/2	S.O.S.
653-654	.AY-AZ		9	2	
655-656	.BA-BB		7	3	
657-658	.BC-BD		13	3	
659-660	.BE-BF		H	2	
661-662	.BG-BH		I	4	
663-664	.BI-BJ		7H	4	
665-666	.BK-BL		9H	3	
667-668	.BM-BN		2I	4-1/2	
669-670	.BO-BP		13H	3	
671-672	———	H	2A	1-1/2	Dolphin
673-674			9A	1-1/2	
675-676			7A	3	
677-678			13A	3	
679-680	16MAR89.BQ-BR	H	1	2	S.O.S.; Fixed Base
681-682	.BS-BT		4	4	
683-684	.BU-BV		6	5-1/2	
685-686	.BW-BX		A	2	
687-688	.BY-BZ		H	3	
689-690	.CA-CB		C	5	
691-692	.CC-CD		C	3	-Reduced Roll Input Amplitude, B.W.
693-694	.CE-CF		1A	2	
695-696	.CG-CH		4H	5	
697-698	.CI-CJ		6C	7-1/2	
699-700	.CM-CN		2H	4	
701-702	17MAR89	H	1A	2*	Slalom
703-704			1G	4-1/2*	
705-706			1I	6*	
707-708			2A	2	Dolphin
709-710			4A	3	
711-713			7A	3	
714-715			13A	2-1/2	
716-718			1H	4	
719-720			1C	7	
721-723			4C	6	
724-725			1H	3	Combined-Axis
726-727			5H	4-1/2	
728-729			5C	6	
730-731			2F	4	
732-733			2G	3	
734-735			2A	2	
736-737			2I	4	
738			9H	2	
739-740			7H	4	
741			2A	1-1/2	Slalom

*Pilot Was Excessively Aggressive for these Runs - Not used in analysis

TABLE B-3. RUN LOG FOR LAMARS SIMULATION (CONTINUED)

RUN NO.	DFA RUN NO.	PILOT	CONF.	HQR	COMMENTS
742-743	17MAR89	H	2G	3	Slalom
744-745			2I	3	
746-747			13H	2-1/2	Combined-Axis
748-749			13C	5-1/2	
750-751			7B	6	
752-753			4I	3	
754-755			6C	7-1/2	
756-757	20MAR89.AA-AB	B	2	2-1/2	S.O.S.
758-759	.AC-AD		4	4	
760-761	.AE-AF		1	1-1/2	
762-763	.AG-AH		5	5-1/2	
764-765	.AI-AJ		13	2-1/2	
766-768	.AK-AM		6	6	
769-770	.AN-AO		H	2-1/2	
771-772	.AP-AQ		I	2	
773-774	.AR-AS		C	5	
775-777	.AT-AV		B	4	
778-781	.AW-AZ		C	4-1/2	-Low F.F. Bandwidth
782-784	.BA-BC		2H	5	
785-786	.BD-BE		5H	5-1/2	
787-788	.BF-BG		4I	4-1/2	
789-791	.BH-BJ		5C	7	-Low Roll F.F. Bandwidth
792-793	——	W	2H	2*	Dolphin
794-796			4H	3*	
797-798			13H	4	
799-800			5H	7*	
801-802			2H	2*	Slalom
803-804			2I	4*	
805-806			2B	8*	
807			2C	10*	
808-809	21MAR89.AF-AG	W	1	2	S.O.S.
810-811	.AH-AI		2	3	
812-813	.AJ-AK		9	4	
814-816	.AL-AN		5	5	
817-818	.AO-AP		4	5	
819-820	.AQ-AR		A	3	
821-822	.AS-AT		H	2	
823-824	.AU-AV		I	5	
825-827	.AW-AY		B	6	
828-830	.AZ		1A	2	-No DFA for Runs 828, 830
831-832	.BA-BB		2H	3	
833-835	.BC-BD		4H	5	-No DFA for Run 833
836-837	.BE-BF		2B	6	
838-839	.BG-BH		5H	6	

*First Session; Pilot Chose Excessively High Sensitivities, Resulting in PIOs; Cases Rerun in Later Session - Not used for Analysis

TABLE B-3. RUN LOG FOR LAMARS SIMULATION (CONTINUED)

RUN NO.	DFA RUN NO.	PILOT	CONF.	HQR	COMMENTS
840-842	21MAR89.BI-BJ	B	2H	4-1/2	S.O.S.; No DFA for Run 840
843-845	.BK-BM		4I	5	
846-847	.BN-BO		T6	2	
848-850	.BP-BR		2 T6	2-1/2	
851-853	.BS-BU		4 T6	4	
854-856	.BV-BX		HT6	2-1/2	
857-859	.CA-CB		2HT6	3-1/2	-No DFA for Run 857
860-862	.CC-CE		4HT6	5	
863-864	———	B	2H	1	Dolphin
865-866			5H	2-1/2	
867-868			2H	1	Slalom
869-871			2B	6	
872-873	———	W	2H	3*	Dolphin
874-875			4H	6*	
876-878			5H	6	
879-880			2H	3**	
881-882			4H	4**	
883-884			2H	4*	Slalom
885-886			2F	7	
887-888			2B	8*	
889-890			2H	4**	
891-892			2B	7**	
893-894			2H	4*	Combined-Axis
895-897			2I	4*	
898-899			5H	6*	
900-901			1H	5*	
902-903			2H	3*	Dolphin
904-905			1H	4	
906-907			4H	6*	
908-909			6H	8*	Slalom
910-911			2H	2*	
912-913			2G	1	
914-915			2C	9*	
916-917			2H	3*	Combined-Axis
918-919			4I	7*	
920-921			2H	3**	Dolphin
922-924			4H	4**	
925-927			5H	4**	
928-929			6H	6**	
930-931			2H	2**	Slalom
932-933			2I	3**	
934-935			2B	7**	

*Pilot Chose Excessively High Sensitivities, Resulting in PIOs - Not used in Analysis

**Fixed Sensitivity - Data used for Analysis

TABLE B-3. RUN LOG FOR LAMARS SIMULATION (CONCLUDED)

RUN NO.	DFA RUN NO.	PILOT	CONF.	HQR	COMMENTS
936-937		W	2H	2**	Combined-Axis
938-939			2B	6**	
940-941			5H	6**	
942-944			4I	7**	
945-947			4H	5**	
948-949			5B	9**	
950-952			2I	5**	
953-954			2H	2**	
955-956			1H	3**	
957-958			6H	7**	
959-960			2C	10**	
961-962			1H	4**	Slalom
963-964			2C	9**	
965-967	23MAR89	S	2H	4+	Dolphin
968-969			4H	6+	
970-971			5H	6+	
972-973			2H	2	
974-975			4H	3	
976-977			5H	3	
978-980			1H	4	
981-982			6H	5	
983-985			7H	5-1/2	
986-987			9H	4	
988-989			13H	4	
990-991			2H	4	Slalom
992-994			2I	5	
995-996			2H	4	
997-998			2B	5	
999-1000			2H	2	
1001-1002			2C	6	
1003-1004			2I	4	
1005-1006			2H	4	Combined-Axis
1007-1008			4H	5	
1009-1010			2B	5	
1011-1012			5H	5	
1013-1014			2H	4	
1015-1016			4H	5	
1017-1018			6H	5	
1019-1020			2C	6	
1021-1022			4I	4	
1023-1024			5B	5	
1025-1026			2H	3	

**Fixed Sensitivity - Data used for Analysis

+First Session; Cases Later Rerun - Not used for Analysis

TABLE B-4. EXPERIMENTAL RESULTS

PILOT M

			PITCH LOOP									ROLL LOOP									SPEED LOOP							
RUN	CASE	HQR	Kc	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	Kc	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA
14FEB89.AN	1	2	6	0.08	1.02	0.52	2.54	44.6	-19	0.21	0.63																	
14FEB89.AO	1		6	0.08	1.07	0.54	2.18	50.4	-24	0.25	0.27																	
14FEB89.AP	4	4	3.5	0.09	1.4	0.55	1.65	59.0	-30	0.3	0.05																	
14FEB89.AQ	4		3.5	0	1.5	0.52	1.42	65.9	-20	0.31	-0.03																	
14FEB89.AR	6	6.5	2	0.07	2	0.61	0.8	74.9	-14	0.43	-0.07																	
14FEB89.AS	6		2	0.07	2	0.63	0.89	74.5	-15	0.33	-0.02																	
14FEB89.AT	A	4										-0.3	6.74	0.5	1.86	60.0	-20	0.28	0	0.6								
14FEB89.AU	A											-0.8	6.64	0.45	1.69	65.4	-24	0.28	-0.08	0.6								
14FEB89.AV	H	4										-0.6	8.78	0.49	1.35	56.7	-25	0.45	-0.1	0.65								
14FEB89.AW	H											-0.1	7.58	0.46	1.65	53.8	-24	0.39	-0.05	0.65								
14FEB89.AX	C	5.5										-0.0	12.6	0.91	1.2	32.8	-21	0.64	0.16	1.2								
14FEB89.AY	C											0.54	12.1	1.1	1.34	40.8	-15	0.64	-0.08	1.2								
14FEB89.AZ	4 6	4	2.5	-0.0	1.48	0.77	1.61	51.0	-10	0.15	0.69										0.03	0.84	1.33	0.44	54.8	-35	-0.5	0.37
14FEB89.BA	4 6		2.5	0.02	1.44	0.7	1.58	54.7	-21	0.3	0.2										0.14	0.62	0.89	0.4	48.4	-92	5.38	-0.59
14FEB89.BB	1 A	4	5.5	0.02	1.14	0.5	2	57.1	-24	0.25	0.1	-1.5	7.72	0.55	1.61	67.9	-19	0.25	-0.06	0.6								
14FEB89.BC	1 A		5.5	0.1	1.05	0.59	2.05	56.9	-25	0.08	0.82	-0.7	7.81	0.53	1.75	59.5	-13	0.32	-0.07	0.6								
14FEB89.BD	4 H	5	2.5	-0.0	1.67	0.79	1.2	70.5	-14	0.26	0.03	-0.8	10.5	0.67	1.57	57.1	-18	0.25	0.24	0.6								
14FEB89.BE	4 H		2.5	0.09	1.64	0.8	1.53	75.6	-13	0.26	-0.23	-1.1	9.07	0.66	1.65	46.7	-20	0.42	0.06	0.6								
14FEB89.BF	6 C	7	2	0.37	2.44	0.64	0.52	102.	-21	0.31	-0.19	-1.2	15.8	0.92	1.29	28.0	-30	1.39	-1.01	1.4								
14FEB89.BG	6 C		2	-0.2	2.08	0.49	0.43	103.	-20	-1.0	0.1	-1.2	11.8	0.59	1.19	39.8	-33	1.1	-0.62	1.4								
14FEB89.BH	4 H 6	4	2.2	-0.2	1.76	0.72	0.78	82.4	-20	-0.0	0.14	0.83	9.69	0.62	1	66.7	-18	0.41	-0.05	0.4								
14FEB89.BI	4 H 6	4.5	2.2	0.01	1.75	0.74	0.94	73.2	-23	-0.0	0.35	-0.1	9.5	0.65	0.85	84.9	-9	0.27	-0.13	0.4	0	0.97	1.63	0.64	16.9	-35	0.13	0.76
14FEB89.BJ	4 H 6		2.2	0	1.74	0.74	0.99	75.0	-27	-0.1	0.35	-1.1	9.79	0.67	0.95	71.2	-23	0.42	-0.1	0.4	0.21	0.88	1.34	0.46	25.9	-54	1.09	0.27
14FEB89.BK	1	2.5	2.4	0.04	1.32	1.04	1.64	64.6	-18	0.29	-0.07																	
14FEB89.BL	1		2.4	0.11	1.38	0.98	1.33	65.8	-28	0.1	0.37																	
14FEB89.BM	1		2.4	0.08	1.32	0.99	1.53	65.5	-18	0.08	0.45																	
14FEB89.BN	2	3	2	0.14	1.3	0.8	1.58	66.5	-16	0.31	-0.15																	
14FEB89.BO	2		2	0.1	1.25	0.78	1.71	70.2	-21	0.24	-0.13																	
14FEB89.BP	4	4	2.2	0.14	1.57	0.77	1.26	64.7	-23	0.31	0.05																	
14FEB89.BQ	4		2.2	0.04	1.61	0.71	1.15	67.7	-17	0.29	0.06																	
14FEB89.BR	6	6	0.8	0.01	2.13	1.17	0.54	77.0	-21	0.06	0.1																	
14FEB89.BS	6		0.8	-0.1	1.97	1.19	0.58	81.7	-20	0.13	0.04																	
14FEB89.BT	H	2										-1.1	7.78	0.65	1.98	44.9	-25	0.51	-0.47	0.6								
14FEB89.BU	H											-0.0	6.46	0.59	1.98	47.5	-18	0.37	-0.02	0.6								
14FEB89.BV	H											0.26	6.37	0.52	1.71	52.6	-20	0.41	-0.11	0.6								
14FEB89.BW	C	4.5										0.31	9.43	0.96	1.32	40.0	-20	0.61	-0.01	1								
14FEB89.BX	C											-1.2	8.62	0.97	1.29	43.8	-19	0.56	0.01	1								

Note: All runs from 14FEB89.AN through 14FEB89.BJ were <u>fixed-base</u>.

TABLE B-4. (CONTINUED)

PILOT M

				PITCH LOOP								ROLL LOOP									SPEED LOOP							
RUN	CASE	HQR	Kc	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	Kc	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA
15FEB89.AK	1	2	5	-0.0	1.19	0.62	2.13	55.4	-24	0.13	0.66																	
15FEB89.AL	1		5	-0.0	1.03	0.57	2.23	49.6	-20	0.4	-0.45																	
15FEB89.AM	H	3										0.09	6.15	0.46	1.58	57.6	-19	0.37	-0.07	0.6								
15FEB89.AN	H											-0.3	6.03	0.44	1.6	58.4	-18	0.31	0.05	0.6								
15FEB89.AO	6	1																						N/A				
15FEB89.DA	1 H	3	5	0.01	1.05	0.57	2.12	58.9	-31	0.31	-0.25	-0.2	6.37	0.37	1.21	82.9	-17	0.37	-0.41	0.8								
15FEB89.DB	4 H	5	3	0.09	1.56	0.57	1.28	67.4	-19	0.39	-0.15	-0.3	6.26	0.33	1.22	74.8	-24	0.17	0.05	0.8								
15FEB89.DC	4 H		3	-0.0	1.51	0.59	1.53	72.8	-19	0.39	-0.46	-1.0	6.04	0.32	1.33	72.1	-18	0.38	-0.28	0.8								
15FEB89.DD	4 C	5.5	3	0.2	1.55	0.62	1.44	73.2	-18	0.32	-0.24	-1.4	8.34	0.62	1.22	33.0	-30	0.99	-0.37	1.1								
15FEB89.DE	4 C		3	0.16	1.43	0.6	1.63	64.4	-10	0.3	-0.1	-2.8	8.28	0.56	1.11	27.5	-28	0.81	0.09	1.1								
15FEB89.DF	4 H 6	6	3	0.25	1.56	0.54	1.68	65.5	-26	0.34	-0.26	-0.6	6.7	0.32	1.37	72.8	-17	0.26	-0.1	1.1	0.92	1.73	2.54	0.29	29.3	-23	2.37	0.1
15FEB89.DG	4 H 6		3	0.12	1.33	0.58	1.71	70.3	-32	0.31	-0.35	-1.6	6.6	0.32	1.48	67.4	-16	0.29	-0.09	1.1	0.52	1.02	1.29	0.44	22.9	-39	1.39	0.23

TABLE B-4. (CONTINUED)

PILOT V

RUN	CASE	HQR	Kc	PITCH LOOP EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	ROLL LOOP EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	Kc	SPEED LOOP EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA
15FEB89.DH	1	4	1.5	-0.1	1.29	1.6	1.69	47.5	-22	0.34	0.24																	
15FEB89.DI	1		2	-0.0	1.22	1.41	1.98	38.2	-27	0.33	0.43																	
15FEB89.DJ	2	4	2	0.04	1.22	0.99	2.44	40.8	-18	0.23	0.7																	
15FEB89.DK	2		2	0.11	1.28	0.98	1.91	38.0	-32	0.36	0.37																	
15FEB89.DL	4	5	2	0.09	1.61	1.1	1.74	36.9	-29	0.4	0.33																	
15FEB39.DM	4		2	0.08	1.57	1.01	1.61	42.1	-32	0.36	0.38																	
15FEB89.DN	1	2	3	0.18	1.13	0.93	2.22	32.2	-25	0.35	0.48																	
15FEB89.DO	1		3	0.1	1.13	0.87	1.94	39.7	-34	0.29	0.57																	
15FEB89.DP	6	7	1	0.19	2.02	1.22	0.77	72.0	-18	0.39	0																	
15FEB89.DQ	6		1	-0.2	1.95	1.29	1	70.4	-17	0.37	-0.04																	
15FEB89.DR	A	2										-1.7	6.25	0.26	1.93	38.0	-22	0.35	0.42	1								
15FEB89.DS	A											-1.6	5.67	0.24	2.23	35.8	-28	0.25	0.82	1								
15FEB89.DT	H	4										-1.5	7.33	0.33	1.86	30.2	-25	0.33	0.79	1								
15FEB89.DU	H											-1.5	6.96	0.34	1.98	28.8	-23	0.47	0.23	1								
15FEB89.DV	C	8										-2.2	14.2	0.87	1.44	16.7	-24	0.74	0.18	1.5								
15FEB89.DW	C											-4.7	11.3	1.15	1.82	41.7	-55	0.67	-0.71	1.5								
15FEB89.DX		6 NR																			-0.1	0.59	1.04	0.46	49.4	7	1.14	0.09
15FEB89.DY	1 A	5	2	0.03	1.72	1.06	1.16	53.7	-24	0.3	0.32	-1.0	6.25	0.3	2.05	51.9	-26	0.17	0.6	1								
15FEB89.DZ	1 A		2.5	0.26	1.42	0.98	1.59	49.1	-18	0.36	0.19	-0.3	6.23	0.33	2.38	39.7	-20	0.3	0.34	1								
15FEB89.EA	1 A		3	0.33	1.32	0.79	1.61	51.7	-29	0.16	0.64	-0.5	6.41	0.34	2.31	42.2	-27	0.26	0.46	1								
15FEB89.EB	1 H		3	0.32	1.31	0.75	1.49	59.6	-25	0.09	0.57	-0.7	8.26	0.48	1.93	42.6	-10	0.28	0.51	1								
15FEB89.EC	1 H		3	0.23	1.22	0.83	1.67	52.6	-28	0.22	0.45	-0.5	7.67	0.54	1.8	49.1	-34	0.41	-0.04	0.8								
15FEB89.ED	1 H	4	3	0.46	1.33	0.81	1.73	55.1	-21	0.26	0.25	-0.5	7	0.58	2.02	37.6	-17	0.35	0.35	0.6								
15FEB89.EE	1 H		3	0.17	1.14	0.9	2.28	45.7	-15	0.34	-0.02	-0.5	7.53	0.73	1.83	53.6	-9	0.52	-0.58	0.6								
15FEB89.EF	2 H	4	1.5	0.3	1.29	1.04	2.3	64.7	-5	0.28	-0.46	-0.7	7.15	0.58	1.63	44.5	-26	0.45	0.04	0.6								
15FEB89.EG	2 H		1.5	0.14	1.17	1.05	2.46	76.9	-19	0.29	-1.21	-1.4	7.34	0.68	1.68	44.2	-27	0.52	-0.15	0.6								
15FEB89.EH	4 H		1.2	0.27	1.69	1.4	1.28	60.8	-16	0.42	-0.05	-0.7	8.11	0.66	1.71	48.5	-22	0.53	-0.33	0.6								
15FEB89.EI	4 H	5	1.5	0.3	1.57	1.19	1.54	60.0	-22	0.5	-0.39	0.59	7.59	0.79	2.21	33.8	-19	0.38	0.23	0.6								
15FEB89.EJ	4 H		1.5	0.37	1.57	1.18	1.5	57.1	-12	0.38	-0.01	0.5	8.42	0.72	1.64	41.1	-9	0.54	-0.1	0.6								
15FEB89.EK	1 A	3	3	0.08	1.12	0.9	2.16	48.4	-24	0.25	0.39	-0.8	6.36	0.45	1.63	48.8	-19	0.45	-0.06	0.6								
15FEB89.EL	1 A		3	0.26	1.06	0.91	2.32	48.9	-21	0.2	0.59	-0.5	6.02	0.51	1.97	43.5	-25	0.27	0.5	0.6								

TABLE B-4. (CONTINUED)

PILOT S

RUN	CASE	HQR	Kc	PITCH LOOP EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	ROLL LOOP EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	Kc	SPEED LOOP EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA
16FEB89.AS	1	3	4.8	0.1	1.01	0.63	2.54	39.6	-20	0.2	0.92																	
16FEB89.AT	1		4.8	0.01	0.99	0.61	2.43	47.8	-22	0.24	0.34																	
16FEB89.AU	2	3	2.5	0.02	1.08	0.73	2.46	56.4	-14	0.25	-0.08																	
16FEB89.AV	2		2.5	0.03	1.06	0.73	2.52	49.4	-17	0.24	0.22																	
16FEB89.AW	4	5	2	0.15	1.46	1	1.62	51.6	-27	0.32	0.22																	
16FEB89.AX	4		2	0.12	1.44	0.95	1.83	44.0	-19	0.4	0.08																	
16FEB89.AY	4		2.5	0.09	1.42	0.79	1.75	46.6	-21	0.35	0.21																	
16FEB89.AZ	H	3										0.24	5.7	0.34	1.61	56.8	-23	0.37	-0.06	1								
16FEB89.BA	H											-0.2	5.79	0.31	1.59	57.1	-19	0.31	0.08	1								
16FEB89.BB	A	2										-0.3	4.91	0.23	1.74	61.0	-26	0.29	0	0.9								
16FEB89.BC	A											0.03	5.03	0.22	1.79	55.9	-25	0.29	0.13	0.9								
16FEB89.BD	C	6										0.04	7.84	0.69	1.51	37.7	-28	0.42	0.35	1.8								
16FEB89.BE	C											-0.1	7.75	0.66	1.43	45.0	-19	0.38	0.26	1.8								
16FEB89.BF	1 A	5	4.8	0.17	1.35	0.55	1.54	48.1	-26	0.13	0.8	0.41	5.64	0.27	1.45	60.1	-21	0.27	0.14	0.9								
16FEB89.BG	1 A		4.8	0.09	1.2	0.57	1.73	51.5	-31	0.13	0.75	0.32	5.43	0.28	1.48	64.3	-31	0.24	0.09	0.9								
16FEB89.BH	1 A		4.8	0.03	1.22	0.57	1.79	51.3	-27	0.33	0.1	-0.3	6.18	0.26	1.28	58.2	-25	0.33	0.11	0.9								
16FEB89.BI	2 A	4	2.5	0.19	1.15	0.68	1.78	66.6	-24	0.2	0.08	0.19	5.79	0.25	1.58	58.7	-23	0.4	-0.17	1								
16FEB89.BJ	2 A		2.5	0.2	1.22	0.68	2.27	69.0	-6	0.14	0.11	0.68	6.41	0.26	1.36	56.7	-22	0.39	0.01	1								
16FEB89.BK	2 A		2.5	0.18	1.2	0.68	1.89	70.8	-13	0.25	-0.26	0.53	6.05	0.32	1.79	50.7	-24	0.3	0.25	1								
16FEB89.BL	2 H	6	2.5	0.18	1.25	0.71	1.74	66.5	-19	0.2	0.09	0.2	7.01	0.39	1.58	47.6	-23	0.38	0.17	1								
16FEB89.BM	2 H		2.5	0.17	1.26	0.65	1.83	70.5	-16	0.2	-0.08	0.14	6.23	0.34	1.68	52.8	-22	0.34	0.1	1								
16FEB89.BN	2 H		2.5	0.12	1.19	0.67	1.74	69.4	-28	0.12	0.23	1.41	6.61	0.32	1.34	53.3	-24	0.31	0.23	1								
16FEB89.BO	4 H	6	3	0.2	1.37	0.68	1.67	58.6	-18	0.3	0.05	-0.5	6.92	0.37	1.3	51.1	-27	0.36	0.19	1.2								
16FEB89.BP	4 H		3	0.16	1.48	0.62	1.53	61.0	-8	0.24	0.2	0.26	6.24	0.33	1.64	53.8	-22	0.44	-0.18	1.2								
16FEB89.BQ	1 C	7	3	0.2	1.6	0.76	1.18	58.8	-24	0.34	0.15	1.71	9.67	0.69	1.61	31.2	-41	0.7	-0.23	2.5								
16FEB89.BR	1 C		3	0.01	1.47	0.77	1.31	65.4	-27	0.05	0.48	1.56	9.63	0.7	1.8	30.9	-17	0.49	0.28	2.5								
16FEB89.BS	1 A	4	4.8	0.1	1.19	0.54	1.77	49.9	-24	0.22	0.51	-0.2	6.39	0.23	1.44	52.6	-23	0.3	0.24	1.2								
16FEB89.BT	1 A		4.8	0.24	1.1	0.55	1.95	54.1	-25	0.14	0.67	-0.5	5.96	0.25	1.76	49.4	-21	0.32	0.26	1.2								
16FEB89.BU	1 A		4.8	0.29	1.11	0.54	1.87	53.0	-30	0.16	0.62	-0.9	5.84	0.21	1.48	57.3	-26	0.31	0.12	1.2								
16FEB89.BV	4 C	6	3	0.25	1.39	0.6	1.36	75.9	-21	0.11	0.13	0.03	8.55	0.44	1.36	41.9	-21	0.37	0.35	3								
16FEB89.BW	4 C		3	0.22	1.6	0.58	1.19	78.4	-13	0.14	0.04	0.63	11.4	0.59	1.49	39.1	-18	0.4	0.34	3								
16FEB89.BX	2 H	4	3.2	0.26	1.18	0.55	1.95	59.9	-19	0.26	-0.01	0.41	6.58	0.29	1.58	50.3	-19	0.34	0.19	1.4								
16FEB89.BY	2 H		3.2	0.18	1.08	0.55	2.07	58.9	-23	0.31	-0.22	0.84	6.73	0.3	1.42	48.5	-27	0.35	0.25	1.4								
16FEB89.BZ	2 H		3.2	0.03	1.08	0.53	2.35	52.3	-16	0.36	-0.47	-0.4	6.61	0.31	1.39	56.7	-28	0.27	0.22	1.4								
16FEB89.CA	6	1																			-0.0	0.29	0.86	0.86	41.0	-25	1	0.03
16FEB89.CB	2 H 6	6	3.2	0.2	1.34	0.53	1.57	80.3	-28	0	0.27	-1.2	7.62	0.27	1.7	50.9	-13	0.34	0.15	1.4	-0.2	0.92	1.28	0.43	47.1	-36	0.92	0.14
16FEB89.CC	2 H 6		3.2	0.23	1.38	0.59	1.85	56.7	-23	0.21	0.33	-3.5	10.6	0.32	1.15	46.0	-19	0.35	0.33	1.4	-0.1	1.24	1.15	0.39	71.6	-2	-2.7	0.54
16FEB89.CD	2 H 6		3.2	0.22	1.29	0.57	1.92	59.9	-21	0.2	0.26	-2.8	7.16	0.26	1.44	50.7	-32	0.35	0.2	1.4	-0.4	1.06	1.32	0.47	33.5	-18	1.16	0.2

TABLE B-4. (CONTINUED)

PILOT B

			PITCH LOOP									ROLL LOOP									SPEED LOOP							
RUN	CASE	HQR	Kc	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	Kc	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA
17FEB89.AB	1	2	0	0.02	0.99	1.43	2.45	45.1	-16	0.22	0.58																	
17FEB89.AC	1		2.2	0.01	0.95	1.49	2.74	43.3	-16	0.21	0.57																	
17FEB89.AD	2	2.5	2	0	0.91	1.02	3.81	40.3	-19	0.23	-0.12																	
17FEB89.AE	2		2	0.01	0.98	1.06	3.17	52.1	-14	0.27	-0.66																	
17FEB89.AF	4	4	2	-0.0	1.58	1.21	1.76	52.4	-18	0.17	0.59																	
17FEB89.AG	4		2	-0.1	1.42	1.13	1.96	49.5	-18	0.21	0.54																	
17FEB89.AH	2	2	2	0	0.99	0.92	2.18	56.2	-25	0.18	0.41																	
17FEB89.AI	2		2	0.09	0.94	0.99	3.04	42.3	-14	0.15	1.08																	
17FEB89.AJ	6	5	1	0.39	1.9	1.35	1.08	65.7	-6	0.27	0.14																	
17FEB89.AK	6		1	0.16	1.71	1.38	1.13	66.8	-27	0.19	0.2																	
17FEB89.AL	6		1	0.34	1.79	1.4	1.25	74.7	-13	0.14	0.11																	
17FEB89.AM	A	2										0.51	5.67	0.46	2.47	35.7	-21	0.34	0.18	0.6								
17FEB89.AN	A											0.13	5.32	0.4	2.22	37.8	-30	0.29	0.51	0.6								
17FEB89.AO	H	2.5										-0.1	6.12	0.58	2.4	30.1	-15	0.36	0.36	0.6								
17FEB89.AP	H											0.14	6.33	0.54	1.91	44.8	-16	0.42	-0.04	0.6								
17FEB89.AQ	C											0.5	13.8	2.66	1.41	32.5	-19	0.81	-0.28	0.6								
17FEB89.AR	C											0.79	10.7	2.04	1.91	22.0	-22	0.67	-0.2	0.7								
17FEB89.AS	C	4.5										0.3	10.2	2.14	2.03	12.8	-27	0.66	-0.05	0.75								
17FEB89.AT	C											0.12	9.74	1.87	1.8	39.6	-28	0.79	-0.98	0.75								
17FEB89.AU	1 A	2.5	2	0.03	1.37	1.26	1.51	57.9	-13	0.31	0.12	-0.0	6.73	0.56	1.41	70.1	-23	0.2	0.05	0.6								
17FEB89.AV	1 A		2.2	0.13	1.29	1.19	1.68	53.8	-27	0.2	0.45	-0.0	6.77	0.7	3.2	38.0	-22	0.24	0.47	0.6								
17FEB89.AW	1 A		2.2	0.29	1.16	1.22	2.07	56.1	-19	0.16	0.52	-0.2	6.34	0.67	2.53	41.2	-24	0.22	0.7	0.6								
17FEB89.AX	4 H	5	2	0.1	1.44	0.98	1.64	66.6	-27	0.24	0.01	-0.7	6.6	0.62	1.6	48.7	-31	0.41	0.06	0.6								
17FEB89.AY	4 H		2	0.03	1.65	1	1.35	62.7	-16	0.24	0.19	0.27	7.73	0.85	1.8	45.1	-26	0.34	0.31	0.6								
17FEB89.AZ	4 H		2	0.43	1.76	0.77	0.99	68.8	-14	0.39	-0.02	-0.5	7.07	0.59	1.66	50.2	-23	0.38	0.07	0.6								
17FEB89.BA	2 H	3.5	2	0.13	1.19	0.84	1.72	69.8	-18	0.14	0.17	-0.2	6.74	0.68	2.24	36.8	-16	0.4	-0.02	0.6								
17FEB89.BB	2 H		2	0.03	1.18	0.79	1.58	77.4	-23	0.09	0.12	-0.3	7.07	0.79	2.42	41.8	-19	0.26	0.46	0.6								
17FEB89.BC	2 C		2	-0.0	1.48	0.77	1.07	80.3	-18	0.14	0.01	-0.1	12.9	2.12	1.47	34.9	-15	0.79	-0.37	0.75								
17FEB89.BD	2 C		2	0.19	1.41	0.78	1.2	93.3	-29	-0.1	0.21	-0.5	12.0	1.92	1.4	42.1	-18	0.7	-0.28	0.85								
17FEB89.BE	2 C	4	2	-0.0	1.64	0.85	1.17	69.6	-22	0.14	0.21	-0.4	10.6	1.7	1.72	31.3	-14	0.66	-0.2	0.9								
17FEB89.BF	2 C		2	0.23	1.26	0.8	1.74	77.2	-18	0.06	0.2	-1.0	10.2	1.46	1.99	14.3	-28	0.88	-0.93	0.9								
17FEB89.BG	6 H		1	0.44	1.99	0.97	0.6	77.8	-22	0.07	0.1	-0.8	7.02	0.59	1.45	54.3	-28	0.27	0.27	0.6								
17FEB89.BH	6 H	5.5	1.2	0.16	1.99	0.95	0.72	82.9	-24	0.14	0.01	-0.1	6.59	0.56	1.45	67.2	-23	0.22	0.08	0.6								
17FEB89.BI	6 H		1.2	0	1.99	0.81	0.6	88.2	-20	0.41	-0.13	0.32	6.83	0.45	1.06	76.2	-19	0.43	-0.26	0.6								
17FEB89.BJ	6 H		1.2	0.24	2.01	0.83	0.59	86.7	-22	0.29	-0.07	-0.2	7.08	0.47	1.07	68.1	-21	0.41	-0.1	0.6								
17FEB89.BK	6 H		1.2	0.35	1.89	0.85	0.68	86.9	-20	0.47	-0.18	-0.3	6.94	0.45	1.29	55.6	-22	0.48	-0.09	0.6								
17FEB89.BL	4 C		2	-0.0	1.6	0.79	1.15	82.2	-27	-0.0	0.24	-0.9	10.8	1.38	1.42	36.1	-14	0.76	-0.29	1								
17FEB89.BM	4 C	5	2	-0.2	1.52	0.86	1.54	61.9	-20	0.29	0.05	-0.4	10.6	1.36	1.78	21.9	-25	0.8	-0.42	1.1								
17FEB89.BN	4 C		2	0.07	1.51	0.79	1.29	74.8	-15	0.28	-0.12	0.54	9.69	1.27	1.37	51.0	-22	0.7	-0.43	1.1								

TABLE B-4. (CONTINUED)

PILOT M

			PITCH LOOP									ROLL LOOP									SPEED LOOP							
RUN	CASE	HQR	Kc	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	Kc	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA
21FEB89.AB	1	2	4	0.03	0.94	0.7	2.23	48.2	-27	0.34	-0.1																	
21FEB89.AC	1		4	0.02	0.99	0.71	2.35	53.9	-21	0.28	-0.05																	
21FEB89.AD	2.	3	2.5	0.03	1.05	0.75	2.83	53.4	-4	0.23	-0.07																	
21FEB89.AE	2		2.5	-0.0	1.02	0.7	2.24	72.2	-23	0.14	0																	
21FEB89.AF	4	3	3	-0.0	1.42	0.63	1.64	61.4	-14	0.42	-0.35																	
21FEB89.AG	4		3	-0.1	1.25	0.62	1.93	58.2	-29	0.2	0.31																	
21FEB89.AH	4		3	-0.0	1.38	0.61	1.92	47.2	-24	0.34	0.12																	
21FEB89.AI	5	5	2.6	0.01	1.44	0.53	1.77	62.7	-19	0.27	-0.03																	
21FEB89.AJ	5		2.6	0.06	1.3	0.55	1.87	54.4	-32	0.32	0.01																	
21FEB89.AK	4	3	3.5	0.07	1.39	0.53	1.72	43.7	-34	0.39	0.19																	
21FEB89.AL	4		3.5	0.01	1.3	0.55	1.88	38.1	-26	0.4	0.24																	
21FEB89.AM	6	6	2.5	0.11	1.76	0.59	1.45	58.1	-21	0.43	-0.11																	
21FEB89.AN	6		2.5	0.05	1.71	0.58	1.24	68.2	-27	0.3	0																	
21FEB89.AO	6		2.5	0.22	1.67	0.61	1.71	54.8	-21	0.37	-0.08																	
21FEB89.AP	A	2										-0.4	5.04	0.18	1.92	53.6	-22	0.32	0.03	1.2								
21FEB89.AQ	A											-0.2	4.64	0.22	2.67	44.7	-19	0.35	-0.41	1.2								
21FEB89.AR	H	2										-0.1	5.51	0.26	1.74	51.1	-22	0.44	-0.17	1								
21FEB89.AS	H											0.04	5.78	0.25	1.62	55.6	-19	0.37	-0.03	1								
21FEB89.AT	C	5										0.02	8.17	0.45	1.34	39.2	-24	0.59	0.04	2.2								
21FEB89.AU	C											-0.2	7.77	0.37	1.17	45.9	-21	0.58	0.02	2.2								
21FEB89.AV	1 A	3	4.8	0.11	1.22	0.54	1.86	45	-30	0.35	0.21	-0.9	6.48	0.23	1.28	69.2	-16	0.41	-0.25	1								
21FEB89.AW	1 A		5	0.13	1.21	0.53	1.9	43.8	-27	0.36	0.18	-1.1	5.74	0.21	1.33	66.0	-20	0.34	-0.09	1								
21FEB89.AX	2 H	3.5	4	0.16	1.25	0.45	2.06	48.0	-32	0.52	-0.72	-0.3	6.54	0.28	1.59	52.2	-13	0.41	-0.03	1								
21FEB89.AY	2 H		4	-0.0	1.15	0.44	2.24	50.0	-43	0.37	-0.32	0.14	6.99	0.26	1.17	68.3	-10	0.45	-0.22	1								
21FEB89.AZ	2 C	6	4.6	0.16	1.13	0.42	2.81	42.5	-25	0.21	0.63	-0.4	9.21	0.46	0.94	46.2	-18	0.79	-0.06	1.5								
21FEB89.BA	2 C		4.6	0	1.16	0.39	2.12	58.3	-30	0.35	-0.43	-1.0	9.51	0.46	1.14	24.3	-24	0.76	0.18	1.5								
21FEB89.BB	4 H	4	4.5	0.17	1.39	0.4	1.9	46.0	-28	0.45	-0.22	-0.5	6.89	0.23	0.83	78.6	-14	0.34	-0.08	1								
21FEB89.BC	4 H		4.5	-0.0	1.56	0.42	1.69	52.1	-29	0.21	0.48	-0.7	7.43	0.24	0.91	89.1	-15	0.53	-0.44	1								

TABLE B-4. (CONTINUED)

PILOT V

RUN	CASE	HQR	Kc	PITCH LOOP EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	ROLL LOOP EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	Kc	SPEED LOOP EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA
21FEB89.BE	1	3	3	0.13	1.14	1.03	2.43	27.6	-26	0.26	1.07																	
21FEB89.BF	4	5	2	0.3	1.56	0.97	1.58	43.1	-25	0.53	-0.06																	
21FEB89.BG	4		2	0.01	1.65	1.03	1.66	37.6	-27	0.37	0.44																	
21FEB89.BH	H											-1.7	7.99	0.4	2.1	27	-21	0.43	0.34	1								
21FEB89.BI	H											-0.6	7.73	0.22	2.09	28.3	-17	0.39	0.47	2								
21FEB89.BJ	H	2										-1.5	6.27	0.21	2	38.3	-30	0.45	-0.05	1.5								
21FEB89.BK	C	7										-1.8	11.3	0.84	1.47	32.7	-26	0.44	0.42	2								
21FEB89.BL	C											-1.5	10.7	0.71	1.78	22.8	-26	0.49	0.52	2								
21FEB89.BM	1 A	3	3	0.44	1.49	0.73	1.34	54.3	-26	0.45	0.02	-0.8	7.27	0.25	1.72	54.0	-15	0.35	0.03	1.2								
21FEB89.BN	1 A		4	0.28	1.19	0.63	1.84	49.3	-28	0.25	0.42	-0.7	6.34	0.26	1.68	47.8	-21	0.42	0.02	1								
21FEB89.BO	4 H	6	2	0.43	1.56	0.87	1.37	66.8	-23	0.18	0.21	0.76	10.6	0.41	1.18	49.3	-27	0.47	0.1	1.5								
21FEB89.BP	4 H		2	0.49	1.52	0.86	1.61	60.2	-24	0.47	-0.42	-0.6	8.46	0.38	1.69	46.7	-25	0.34	0.27	1.5								
21FEB89.BQ	2 H	4	2	0.43	1.23	0.83	1.92	62.0	-17	0.27	-0.08	-0.9	7.48	0.43	1.76	43.5	-25	0.47	-0.04	1								
21FEB89.BR	2 H		2.5	0.34	1.16	0.7	1.97	60.3	-34	0.32	-0.27	-0.7	7.74	0.38	1.65	41.6	-22	0.47	0.07	1								
21FEB89.BS	2 C	8	2	0.93	1.67	0.67	0.97	93.6	-25	-0.4	0.34	-1.1	15.5	1.04	1.51	23.8	-31	0.72	0	2								
21FEB89.BT	2 C		2	0.86	1.39	0.83	1.23	95.1	-26	-0.2	0.28	0.57	14.3	1.55	1.21	45.7	-10	0.84	-0.39	1								
21FEB89.BU	4 H	5	2	0.47	1.61	0.92	1.85	46.5	-14	0.45	-0.18	0.2	6.74	0.45	1.43	52.0	-25	0.39	0.09	0.8								
21FEB89.BV	4 H		2	0.43	1.57	0.91	1.66	46.8	-22	0.43	0.02	-0.6	8	0.52	1.49	50.7	-12	0.42	0.04	0.8								
21FEB89.BW	1 A	3	3	0.43	1.31	0.87	1.89	40.0	-24	0.37	0.27	-0.2	6.16	0.3	1.51	59.2	-20	0.44	-0.23	1								
21FEB89.BX	1 A		3	0.45	1.49	0.87	1.62	40.5	-32	0.2	0.83	0.54	6.91	0.3	1.55	51.5	-18	0.48	-0.15	1								
21FEB89.BZ	6 H	8	1	0.31	1.88	1.27	0.94	72.3	-17	0.03	0.26	0.57	7.98	0.34	1.24	53.8	-21	0.54	-0.11	0.8								
21FEB89.CA	6 H		1	0.62	1.96	1.14	0.67	79.6	-12	0.33	-0.03	0.25	9.43	0.43	1.27	43.0	-24	0.56	0.05	0.8								
21FEB89.CB	2 C	8	2	1.24	1.76	0.74	1.53	86.3	-33	0.47	-1.02	0.38	11.7	0.95	1.93	48.4	-43	0.78	-1.56	1.6								
21FEB89.CC	2 C		2	1.07	1.78	0.69	0.9	81.0	-16	-0.2	0.32	1.55	13.0	1.06	1.64	26.3	-13	0.61	0.12	1.6								
21FEB89.CD	A 6	3																			0.17	0.62	1.8	1.09	54.1	-25	0.57	0.11
21FEB89.CE	1 A 6	5	2	0.4	1.86	1.28	1.34	45.2	-20	0.47	0.19	-0.3	6.68	0.29	1.34	55.7	-17	0.47	-0.11	0.8	-0.1	1	1.65	0.65	50.4	-36	1.72	-0.28
21FEB89.CF	1 A 6		2	0.62	1.58	1.21	1.43	44.9	-22	0.29	0.52	-0.7	6.03	0.28	1.43	57.6	-42	0.5	-0.26	0.8	-0.7	1.11	1.83	0.41	60.6	-52	-0.9	0.36
21FEB89.CG	2 H 6	7	2.5	0.6	1.24	0.75	2.42	48.5	-24	0.23	0.39	-0.5	8.17	0.39	1.32	62.5	-26	0.6	-0.45	1	-0.1	1.78	2.43	0.54	32.3	-27	2.21	-0.11
21FEB89.CH	2 H 6		2.5	0.32	1.3	0.74	1.94	53.5	-30	0.31	0.03	-0.6	8.82	0.44	1.46	52.7	-18	0.67	-0.52	1	-0.6	1.63	1.86	0.38	83.4	-15	4.16	-0.54

TABLE B-4. (CONTINUED)

PILOT V

RUN	CASE	HQR	Kc	PITCH LOOP EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	ROLL LOOP EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	Kc	SPEED LOOP EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA
22FEB89.AJ	1	2	2	0.06	1.08	1.39	2.31	35.2	-27	0.37	0.21																	
22FEB89.AK	1		2.5	0.06	1.2	1.16	2.1	29.7	-31	0.43	0.25																	
22FEB89.AL	2	4	2	0.11	1.15	0.93	2.1	39	-25	0.43	-0.07																	
22FEB89.AM	2		2	0.03	1.16	0.9	2.23	54.2	-18	0.17	0.53																	
22FEB89.AN	4	5	2	-0.0	1.51	1.02	1.77	34.2	-30	0.45	0.25																	
22FEB89.AO	4		2	-0.1	1.66	1	1.7	37.1	-18	0.45	0.2																	
22FEB89.AP	H	2										-1.1	7.37	0.34	2.28	24.0	-21	0.33	0.32	1.2								
22FEB89.AQ	H											-1.0	7.86	0.34	2.12	27.2	-14	0.41	0.41	1.2								
22FEB89.AR	B	6										-1.8	9.41	0.71	1.91	21.7	-21	0.6	0.05	2.2								
22FEB89.AS	B											0.15	11.3	0.78	1.59	27.8	-24	0.7	-0.11	2.2								
22FEB89.AT	2 H	3	2	0.16	1.28	0.82	2.16	52.5	-11	0.25	0.2	0.38	8.27	0.33	1.51	42.5	-19	0.47	0.11	1.2								
22FEB89.AU	2 H		2.3	0.31	1.32	0.7	1.66	57.8	-24	0.22	0.29	-0.0	7.2	0.3	1.76	49.2	-30	0.47	-0.2	1.2								
22FEB89.AW	4 A	[illegible]	2	0.5	1.57	0.92	1.6	49.7	-17	0.4	0.06	-0.3	5.99	0.23	1.35	61.8	[illegible]	0.44	-0.18	1								
22FEB89.AX	4 A		2	0.52	1.6	0.85	1.52	55.4	-22	0.47	-0.19	-0.4	6.52	0.24	1.51	59.3	-16	0.43	-0.2	1								
22FEB89.AY	1 B	7	3	0.51	1.41	0.75	1.58	61.8	-23	0.34	-0.09	0.12	10.1	0.65	1.62	43.1	-6	0.59	-0.28	3								
22FEB89.AZ	1 B		3	0.5	1.36	0.76	1.38	53.3	-29	0.53	-0.14	0.18	12.1	0.79	1.76	27.4	-15	0.65	-0.11	3								
22FEB89.BA	4 A 6	7	2	0.62	1.72	0.88	1.31	58.3	-17	0.54	-0.21	0.39	6.91	0.24	1.19	76.5	-21	0.42	-0.34	1	-0.4	2.5	2.61	0.37	30.7	-19	1.91	0.11
22FEB89.BB	4 A 6		2	0.73	1.65	0.96	1.57	43.9	-28	0.55	-0.13	-0.8	6.5	0.25	1.08	67.7	-23	0.35	-0.03	0.75	-0.3	1.67	2.19	0.42	33.8	-57	1.45	0.15
22FEB89.CW	2 A	2	4.5	0.29	1.05	0.41	2.5	45.8	-23	0.27	0.22	-0.2	6.04	0.2	1.74	45.3	-23	0.43	0.03	1.2								
22FEB89.CX	2 A		4.5	0.33	1.14	0.42	2.57	36.5	-24	0.19	1.07	-0.7	5.82	0.2	1.66	48.2	-24	0.4	0.06	1.2								
22FEB89.CY	2 A 6	4	4.5	0.43	1.14	0.4	1.87	62.6	-30	0.09	0.53	-1.1	6.77	0.18	1.35	54.8	-24	0.49	-0.12	1.2								
22FEB89.CZ	2 A 6		4.5	0.38	1.37	0.42	1.96	47.9	-20	0.38	-0.05	-0.5	7.08	0.17	1.33	51.7	-31	0.64	-0.31	1.2	0	1.82	2.37	0.66	34.2	-15	1.08	0.17

TABLE B-4. (CONTINUED)

PILOT M

				PITCH LOOP								ROLL LOOP									SPEED LOOP							
RUN	CASE	HQR	Kc	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	Kc	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA
22FEB89.CA	2	2	2.8	-0.0	1.09	0.64	2.17	52.7	-29	0.31	-0.07																	
22FEB89.CB	2		2.8	-0.1	1.02	0.6	2.09	56.9	-32	0.25	0.11																	
22FEB89.CC	4	3.5	3	0.02	1.39	0.63	1.89	37.8	-26	0.42	0.16																	
22FEB89.CD	4		3	0.05	1.36	0.58	1.69	50.1	-23	0.43	-0.11																	
22FEB89.CE	A	2										0.44	4.92	0.23	1.95	56.4	-28	0.21	0.31	1								
22FEB89.CF	A											0.12	4.84	0.21	1.98	59.7	-17	0.33	-0.25	1								
22FEB89.CG	C	6										0.64	7.68	0.53	1.39	52.0	-18	0.53	-0.17	2.2								
22FEB89.CH	C											0.31	8.26	0.7	1.38	52.8	-12	0.45	-0.03	2.2								
22FEB89.CI	2 A	3	3	-0.0	1.13	0.58	2.35	48.5	-28	0.32	-0.09	0.22	5.49	0.22	1.55	69.0	-20	0.22	0.02	1								
22FEB89.CJ	2 A		3	-0.0	1.11	0.58	2.41	52.8	-21	0.21	0.31	-0.5	5.64	0.21	1.59	62.7	-19	0.48	-0.47	1								
22FEB89.CK	4 A	4	4.5	-0.0	1.43	0.48	1.87	36.7	-28	0.39	0.31	0	5.59	0.2	1.35	71.4	-23	0.24	-0.04	1								
22FEB89.CL	4 A		4.5	-0.1	1.39	0.44	1.84	40.7	-27	0.4	0.19	-0.4	5.94	0.17	1.11	83.3	-28	0.25	-0.2	1								
22FEB89.CM	1 C	7	6	-0.0	1.37	0.41	1.35	69.0	-34	0.28	-0.03	-0.1	8.48	0.47	1.38	45.2	-23	0.77	-0.46	2.2								
22FEB89.CN	1 C		6	0.18	1.36	0.44	1.65	58.5	-24	0.32	0.01	-1.7	10.0	0.5	1.24	48.3	-9	0.74	-0.31	2.2								
22FEB89.CO	4 C	7.5	4.5	-0.1	1.75	0.38	1.47	70.8	-29	0.46	-0.52	-0.6	10.6	0.48	1.17	54.9	-9	0.71	-0.33	2.6								
22FEB89.CP	4 C		4.5	-0.1	1.34	0.39	1.8	59.2	-20	0.37	-0.25	-1.7	7.95	0.29	1.08	37.2	-26	0.73	0.04	2.6								
22FEB89.CQ	6 A	7	2.5	-0.2	1.99	0.49	0.8	87.5	-11	0.17	-0.07	-1.0	6.13	0.16	0.99	104.	-14	0.27	-0.49	1.2								
22FEB89.CR	6 A		2.7	-0.0	1.82	0.46	0.93	86.8	-8	0.45	-0.34	-0.5	6.37	0.15	1.2	67.6	-28	0.3	-0.01	1.2								
22FEB89.CS	2 A 6	5	4.2	0.13	1.28	0.39	1.74	65.2	-28	0.53	-0.88	-1.9	6.68	0.15	0.87	104.	-18	0.48	-0.59	1.2	0.61	1.69	1.29	0.26	53.0	-40	1.6	0.05
22FEB89.CT	2 A 6		4.2	-0.0	1.31	0.37	1.85	74.5	-43	0.71	-1.95	-1.7	5.75	0.17	1.27	78	-19	0.31	-0.24	1.2	0.22	2.03	1.33	0.24	51.9	-25	1.75	0.04
22FEB89.CU	4 A 6	5	4.5	-0.0	1.42	0.4	1.69	47.0	-38	0.46	-0.1	-1.0	6.26	0.17	1.26	76.1	-14	0.26	-0.14	1.2	0.49	2.08	1.42	0.23	58.0	-30	0.14	0.11
22FEB89.CV	4 A 6		4.5	-0.0	1.45	0.39	1.57	55.4	-30	0.57	-0.49	-1.4	6.62	0.15	0.74	89.2	-13	0.28	-0.14	1.2								

TABLE B-4. (CONTINUED)

PILOT V

RUN	CASE	HQR	Kc	PITCH LOOP								ROLL LOOP									SPEED LOOP							
				EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	Kc	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA
23FEB89.AA	2	2	2	-0.0	1.15	0.92	2	36.1	-31	0.3	0.61																	
23FEB89.AB	2		2	0.23	1.37	0.89	1.86	39.1	-20	0.39	0.25																	
23FEB89.AC	5	5	2	0.08	1.5	0.74	1.45	63.6	-26	0.46	-0.31																	
23FEB89.AD	5		2	-0.1	1.42	0.71	1.5	64.2	-15	0.3	-0.02																	
23FEB89.AE	A	2										-0.8	5.14	0.24	2.41	38.9	-20	0.31	0.29	1								
23FEB89.AF	A											-0.5	5.48	0.21	1.92	44.1	-24	0.33	0.29	1								
23FEB89.AG	B	6										0.02	9.18	0.52	1.76	26.3	-23	0.72	-0.28	2.5								
23FEB89.AH	B											-2.2	7.77	0.52	2.02	29.7	-21	0.71	-0.82	2.5								
23FEB89.AI	2 B	7	2	0.75	1.57	0.68	1.48	77.0	-14	0.28	-0.29	-0.7	9.75	0.71	1.93	19.1	-42	0.77	-0.53	2.5								
23FEB89.AJ	2 B		2	0.41	1.63	0.7	1.24	78.6	-13	0.19	-0.04	2.41	10.6	0.72	2	18.5	-8	0.65	-0.17	2.5								
23FEB89.AK	2 6	4	2	0.32	1.59	0.92	1.49	46.6	-34	0.25	0.55										-0.2	1.19	1.62	0.43	66.8	-31	-0.4	0.25
23FEB89.AL	2 6		2	0.08	1.39	0.9	1.79	45.6	-21	0.35	0.2										0.26	1.3	1.76	0.47	51.6	-21	0.92	0.11
23FEB89.AM	5 6	7	2	-0.1	1.42	0.73	1.99	73.2	-8	0.02	0.47										-0.0	1.83	2.28	0.51	43.5	-24	1.59	0
23FEB89.AN	5 6		2	0.06	1.44	0.71	1.68	57.5	-18	0.28	0.12										-0.2	1.52	2.05	0.4	26.7	-59	1.56	0.18

TABLE B-4. (CONTINUED)

PILOT S

RUN	CASE	HQR	Kc	PITCH LOOP EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	ROLL LOOP EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	Kc	SPEED LOOP EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA
23FEB89.BA	1	2	3	0.02	0.96	0.94	2.62	44.5	-24	0.2	0.69																	
23FEB89.BB	1		3	0.09	0.93	0.98	2.72	38.2	-23	0.21	0.86																	
23FEB89.BC	4	3	2	0.12	1.4	1.01	2.02	43.8	-19	0.41	-0.08																	
23FEB89.BD	4		2	0.11	1.34	1.01	2	41.5	-28	0.4	0.05																	
23FEB89.BE	6	6	1.7	0.04	2	0.91	1.38	64.8	-5	0.2	0.22																	
23FEB89.BF	6		1.7	-0.0	1.89	0.94	1.46	56.1	-17	0.52	-0.26																	
23FEB89.BG	H	3										0.07	5.6	0.29	1.96	52.6	-28	0.46	-0.5	1.1								
23FEB89.BH	H											0.42	5.41	0.3	1.91	60.1	-20	0.47	-0.74	1.1								
23FEB89.BI	C	5										1.55	8.53	0.63	1.51	32.6	-19	0.58	0.11	1.7								
23FEB89.BJ	C											0.13	7.53	0.57	1.79	29.4	-15	0.72	-0.42	1.7								
23FEB89.BK	1 H	5	3	0.15	1.17	0.85	1.81	45.1	-28	0.24	0.6	0.02	5.9	0.32	1.6	55.5	-23	0.36	0.01	1								
23FEB89.BL	1 H		3	0.13	1.21	0.83	1.8	47.0	-23	0.28	0.39	0.11	6.31	0.34	1.52	51.0	-29	0.41	0.02	1.1								
23FEB89.BM	1 H		3	0.14	1.1	0.82	1.89	47.4	-31	0.26	0.44	0.51	6.68	0.31	1.49	57.7	-18	0.39	-0.06	1.1								
23FEB89.BN	6 H	6	1.3	0.2	1.75	1.1	1.33	68.7	-10	0.24	0.07	1.14	7.04	0.26	1.06	57.7	-21	0.39	0.1	1.1								
23FEB89.BO	6 H		1.3	0.11	1.81	1.07	1.02	69.8	-13	0.22	0.13	-0.7	6.5	0.3	1.45	58.8	-26	0.45	-0.2	1.1								
23FEB89.BP	4 H	5	2	0.2	1.48	0.89	1.77	60.5	-22	0.41	-0.42	-0.3	6.62	0.26	1.37	51.3	-25	0.33	0.23	1.2								
23FEB89.BQ	4 H		2	0.25	1.41	0.9	1.81	48.9	-19	0.42	-0.13	-0.2	6.58	0.33	1.79	49.3	-14	0.43	-0.09	1.2								
23FEB89.BR	4 H		2	0.19	1.33	0.84	1.76	55.1	-20	0.4	-0.2	-0.6	6.66	0.28	1.32	58.0	-27	0.4	-0.02	1.2								
23FEB89.BS	6 C	7	1.7	0.04	2.2	0.9	0.81	71.3	-21	0.14	0.17	-2.0	15.4	1.04	1.43	27.4	-20	0.86	-0.29	1.9								
23FEB89.BT	6 C		1.7	-0.3	1.96	0.86	0.83	67.5	-30	0.1	0.25	-1.1	11.7	0.88	1.63	27.3	-26	0.75	-0.25	1.9								
23FEB89.BU	1 6	4																			-0.2	1.28	3.87	0.57	1.9	-54	4.19	-0.48
23FEB89.BV	1 6	6	3.3	0.18	1.5	0.92	1.93	36.4	-27	0.51	-0.17										-0.0	1.8	2.71	0.39	38.7	-34	1.91	0.05
23FEB89.BW	1 6		3.3	0.16	1.14	0.84	1.91	51.5	-33	0.27	0.26										-0.1	1.51	2.88	0.83	28.7	-5	0.93	0.296
23FEB89.BX	6 6	6	2	0.08	1.79	0.8	1.18	66.4	-27	0.46	-0.16										-0.4	1.73	2.24	0.41	36.9	-36	1.3	0.15
23FEB89.BY	6 6		2	0.14	1.74	0.83	1.94	45.7	-21	0.41	-0.1										-0.1	2.18	3.22	0.44	33.2	-10	1.63	0.11
23FEB89.BZ	H 6	5										-0.1	7.59	0.27	1.72	64.6	-15	0.31	-0.15	1.7	-0.1	0.77	1.82	0.65	61.8	-29	1.22	-0.2
23FEB89.CA	H 6											-0.3	6.64	0.25	2.16	38.7	-35	0.32	0.39	1.7	0.03	1.07	2.25	0.59	86.9	-51	-3.5	1.26
23FEB89.CB	C 6	5										-2.2	8.41	0.48	1.58	39.5	-24	0.61	-0.17	2.1								
23FEB89.CC	C 6											-0.3	9.07	0.54	1.42	39.5	-18	0.55	0.05	2.1	0.28	1.02	2.14	0.72	30.8	-24	1.46	-0.01
23FEB89.CD	1 H 6	6	3.5	0.08	1.33	0.87	1.85	46.3	-29	0.14	0.88	-2.3	8.05	0.44	1.05	60.8	-20	0.33	0.11	1.1	-0.5	1.78	3.18	0.79	14.0	-45	0.79	0.58
23FEB89.CE	1 H 6		3.5	-0.0	1.04	0.81	2.14	40.0	-28	0.31	0.4	-0.7	6.62	0.34	1.53	55.7	-22	0.34	0.07	1.1	-0.0	1.58	2.49	0.48	47.6	-18	1.16	0.09

TABLE B-4. (CONTINUED)

PILOT B

				PITCH LOOP								ROLL LOOP									SPEED LOOP							
RUN	CASE	HQR	Kc	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	Kc	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA
24FEB89.AA	1	2	2.2	0.01	0.92	1.3	2.34	38.0	-34	0.3	0.47																	
24FEB89.AB	1		2.2	0.1	0.91	1.33	2.67	37.4	-21	0.18	1.11																	
24FEB89.AC	2	3	2	0.06	1.02	0.93	2.45	44.4	-14	0.19	0.81																	
24FEB89.AD	2		2	0.01	0.94	0.87	2.37	48.4	-26	0.3	0.01																	
24FEB89.AE	4	3.5	2	-0.0	1.3	1.02	2.09	41.4	-21	0.33	0.29																	
24FEB89.AF	4		2	0.07	1.28	0.98	1.99	44.3	-20	0.22	0.65																	
24FEB89.AG	A	2										-0.3	5.75	0.33	2.6	47.8	-24	0.19	0.58	1								
24FEB89.AH	A											0.34	5.19	0.24	2.05	53.3	-22	0.27	0.15	1								
24FEB89.AI	C	4.5										0.48	11.6	1.49	1.69	38.8	-22	0.59	-0.19	1.4								
24FEB89.AJ	C											0.47	10.7	1.25	1.78	27.1	-26	0.66	-0.15	1.4								
24FEB89.AK	H	3										0.4	6.09	0.39	1.71	58.3	-31	0.29	0.09	1								
24FEB89.AL	H											-0.8	6.41	0.35	1.77	52.2	-26	0.4	-0.09	1								
24FEB89.AM	2 A	3	2	0.19	1.17	0.86	1.68	67.4	-33	0.16	0.19	-0.0	6.37	0.46	2.87	66.0	-27	-0.0	1.43	1								
24FEB89.AN	2 A		2	0.14	1	0.91	2.22	58.5	-25	0.26	-0.07	-0.1	6.84	0.58	2.8	54.8	-13	0.22	-0.01	1								
24FEB89.AO	1 C		2	0.24	1.91	0.89	0.9	72.7	-28	0.11	0.18	1.85	17.7	2.17	1.71	42.3	-22	0.44	0.12	1.4								
24FEB89.AP	1 C	5.5	2	0.08	1.87	0.89	0.84	64.9	-33	0.27	0.17	-0.9	13.7	1.59	1.53	62.4	-36	0.18	0.27	1.6								
24FEB89.AQ	1 C		2	0.38	1.69	0.9	0.97	69.3	-23	0.04	0.31	-0.0	16.7	1.93	1.41	30.8	-27	0.56	0.23	1.6								
24FEB89.AR	4 A	4.5	2	0.22	1.54	0.98	1.79	47.8	-29	0.3	0.31	0.1	7.8	0.59	2.38	47.2	-11	0.48	-1.01	1								
24FEB89.AS	4 A		2	0.45	1.54	0.96	1.66	50.5	-17	0.34	0.17	-0.3	8.41	0.65	2.33	42.6	-23	0.14	1.12	1								
24FEB89.AT	4 A		2	0.25	1.53	0.96	1.55	49.4	-29	0.25	0.47	0.13	6.73	0.48	2.79	38.6	-19	0.34	-0.17	1								
24FEB89.AU	1 H	5	2	0.54	1.57	1.15	1.31	54.4	-25	0.43	0.07	0.51	9.81	1	2.41	34.0	-27	0.33	0.36	1								
24FEB89.AV	1 H		2	0.21	1.46	1.11	1.32	59.3	-28	0.21	0.33	-0.3	9.58	0.82	1.93	55.1	-4	0.44	-0.48	1.2								

TABLE B-4. (CONTINUED)

PILOT V

				PITCH LOOP								ROLL LOOP									SPEED LOOP							
RUN	CASE	HQR	Kc	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	Kc	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA
24FEB89.DA	4	4	2	-1.1	3.38	8.9	0.42	60.5	-18	0.47	0.12																	
24FEB89.DB	4		2	0.05	1.68	1.02	1.58	32.6	-22	0.49	0.32																	
24FEB89.DC	5	6	2	-0.0	1.32	0.75	1.78	60.7	-27	0.42	-0.47																	
24FEB89.DD	5		2	-0.1	1.5	0.78	1.59	57.1	-36	0.26	0.23																	
24FEB89.DE	A	1										0.2	5.51	0.2	1.95	47.0	-21	0.43	-0.19	1								
24FEB89.DF	A											0.3	5.66	0.23	1.94	46.7	-21	0.42	-0.16	1								
24FEB89.DG	H	3										-0.2	7.23	0.3	1.84	33.9	-20	0.51	0.05	1								
24FEB89.DH	H											0.54	7.77	0.32	1.8	32.0	-18	0.5	0.19	1								
24FEB89.DI	B	6										-1.2	9.61	0.7	1.67	29.4	-27	0.61	0.01	2								
24FEB89.DJ	B											0.16	8.54	0.75	1.89	23.9	-21	0.64	-0.15	2								
24FEB89.DK	2 A	3	2	0.39	1.41	0.8	1.55	58.5	-22	0.32	0.06	0.33	6.46	0.22	1.68	57.2	-19	0.37	-0.11	1								
24FEB89.DL	2 A		2	0.25	1.34	0.82	1.59	57.0	-34	0.29	0.16	0.42	6.48	0.19	1.32	56.6	-25	0.5	-0.16	1								
24FEB89.DM	5 A	5	2	-0.0	1.4	0.69	1.72	63.1	-9	0.38	-0.35	0.19	6.82	0.19	1.4	61.2	-24	0.39	-0.11	1								
24FEB89.DN	5 A		2	0.26	1.49	0.74	1.55	62.2	-18	0.35	-0.1	0.62	6.14	0.2	1.44	60.3	-25	0.5	-0.33	1								
24FEB89.DO	5 B	8	1.75	0.77	1.54	0.68	1.16	97.6	-6	-0.2	0.19	2.02	10.4	0.81	1.66	34.3	-41	0.68	-0.29	2								
24FEB89.DP	5 B		1.75	0.44	1.8	0.64	0.9	91.8	-16	0.27	-0.25	2.52	12.6	0.87	0.89	93.9	-11	0.9	-0.79	2								
24FEB89.DQ	6	1																										
24FEB89.DR	1 6	5	1.75	0.69	1.92	1.5	1.32	38.3	-28	0.64	0.07										-0.0	2.16	3.05	0.45	33.8	-31	1.45	0.14
24FEB89.DS	1 6		2.5	0.27	1.6	1.19	1.74	32.1	-32	0.39	0.52										0.77	1.66	2.95	0.34	-2.5	-138	4.6	0
24FEB89.DT	1 6		2.5	0.1	1.32	1.11	1.83	26.7	-38	0.43	0.51																	
24FEB89.DU	4 6	5	2	0.22	1.71	0.94	1.63	36.7	-26	0.51	0.11										0.02	1.93	2.71	0.69	19.5	-7	1.44	0.16
24FEB89.DV	4 6		2	0.05	1.66	0.89	1.46	43.6	-19	0.52	0.05										-0.0	1.41	2.25	0.6	43.9	-29	0.55	0.28
24FEB89.DW	A 6	2										0.78	5.98	0.21	1.6	54.0	-22	0.43	-0.12	1	0.14	0.83	1.69	0.66	52.9	-30	1.38	-0.18
24FEB89.DX	A 6											1.11	5.55	0.21	1.8	49.8	-27	0.19	0.65	1	-0.0	0.74	1.54	1.19	140.	-12	-1.0	0.42
24FEB89.DY	B 6	6										-1.3	10.5	1.13	1.48	41.3	-14	0.73	-0.4	1.5	-0.2	1.17	1.8	0.58	46.5	-30	1.13	0.06
24FEB89.DZ	B 6											2.21	9.19	0.92	1.36	46.0	-17	0.56	-0.07	1.5	0.3	0.81	1.76	0.12	115.	15	1.3	-0.01
24FEB89.EA	H 6	3										0.69	7.79	0.4	1.59	47.8	-22	0.74	-0.74	1	-0.0	1.12	1.99	0.65	47.9	-26	0.12	0.42
24FEB89.EB	2 B 6	7	2	0.57	1.34	0.75	1.59	76.8	-21	0.34	-0.5	0.59	9.51	0.68	1.63	39.7	-16	0.66	-0.36	2	0.05	1.16	2.02	0.49	63.9	-41	-0.5	0.36
24FEB89.EC	2 B 6		2	0.8	1.54	0.78	1.2	75.3	-23	0.16	0.06	-0.1	9.38	0.62	1.47	40.7	-15	0.54	0.02	2	0.34	1.36	2.21	0.59	31.0	-24	1.94	-0.07
24FEB89.ED	5 A 6	8	2	0.47	1.49	0.64	1.5	75.5	-13	0.25	-0.2	-0.3	6.02	0.18	1.19	73.5	-26	0.35	-0.19	1	-0.0	1.97	2.42	0.39	40.6	-18	2.48	-0.06
24FEB89.EE	5 A 6		2	0.31	1.62	0.65	1.39	88.1	-9	-0.1	0.3	0.19	7.37	0.17	0.91	66	-20	0.47	-0.05	1	0.27	1.91	2.1	0.6	47.5	-10	2.87	-0.61
24FEB89.EF	2 H 6	4	2	0.47	1.32	0.85	1.98	41.9	-24	0.44	-0.11	-0.8	7.1	0.3	1.79	53.4	-12	0.38	-0.08	1	-0.3	1.7	2.81	0.59	22.9	-15	1.94	0
24FEB89.EG	2 H 6		2	0.16	1.47	0.85	1.75	45.5	-21	0.46	-0.09	-1.0	7.68	0.3	1.19	67.4	-21	0.53	-0.33	1	0.03	1.74	2.31	0.4	37.7	-37	2.04	0.03
24FEB89.EH	5 B 6	10	2	0.41	1.58	0.69	1.19	90.4	-26	-0.0	0.1	-1.2	13.5	0.77	1.33	37.8	-15	0.82	-0.32	2	0.72	2.22	2.91	0.43	34.3	-12	2.35	-0.03
24FEB89.EI	5 B 6		2	0.12	1.62	0.71	1.17	97.2	-29	-0.3	0.37	1.73	12.9	0.73	1.52	40.4	-28	0.86	-0.72	2	-0.1	2.07	2.9	0.31	-59.	4	-2.0	1.08

TABLE B-4. (CONTINUED)

PILOT M

			PITCH LOOP									ROLL LOOP									SPEED LOOP							
RUN	CASE	HQR	Kc	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	Kc	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA
13MAR89.AA	1	2	4.8	-0.0	1	0.7	2.6	30.1	-24	0.19	1.39																	
13MAR89.AB	1		4.8	-0.0	0.92	0.65	2.77	36.4	-23	0.2	0.98																	
13MAR89.AC	2	3	3	0.04	0.96	0.63	3.02	42.8	-18	0.23	0.27																	
13MAR89.AD	2		3	0.06	0.94	0.6	2.92	43.3	-22	0.22	0.45																	
13MAR89.AE	5	5	2.6	0.01	1.24	0.54	2.09	57.1	-17	0.37	-0.44																	
13MAR89.AF	4	3.5	4	-0.1	1.37	0.5	1.96	30.4	-27	0.42	0.36																	
13MAR89.AG	4		4	-0.0	1.26	0.49	2.01	40.1	-24	0.35	0.27																	
13MAR89.AH	4		4	0.03	1.31	0.47	1.87	39.9	-26	0.4	0.19																	
13MAR89.AI	6	6	2.2	-0.0	1.66	0.68	1.61	52.1	-15	0.41	-0.04																	
13MAR89.AJ	6		2.2	-0.1	1.61	0.7	1.79	50.7	-32	0.37	0.01																	
13MAR89.AK	H	2										-1.6	5.91	0.3	1.99	43.3	-19	0.45	-0.19	1								
13MAR89.AL	H											-1.3	5.43	0.31	1.9	52.3	-19	0.38	-0.15	1								
13MAR89.AM	B	3										-1.2	6.58	0.45	1.87	35.5	-20	0.52	-0.08									
13MAR89.AN	B											-0.8	6.17	0.41	1.82	38.1	-21	0.44	0.19	2.7								
13MAR89.AO	C	6										-1.6	9.41	0.54	0.38	45.9	-31	-19.	3.15	3.3								
13MAR89.AP	C											-0.9	8.05	0.41	1.51	50.0	-21	0.41	0.05	3.3								
13MAR89.AQ	1	2	5.3	0.07	1.02	0.54	2.29	36.9	-30	0.27	0.67																	
13MAR89.AR	1		5.3	0.04	0.98	0.57	2.48	31.0	-27	0.15	1.63																	
13MAR89.AS	14	4	2.2	-0.0	1.08	0.9	2.66	55.8	-23	0.21	0.07																	
13MAR89.AT	14		2.5	-0.0	1.02	0.85	3.06	49.0	-24	0.22	0.02																	
13MAR89.AU	14		2.5	0.02	0.98	0.86	3.19	45.5	-21	0.21	0.25																	
13MAR89.AV	15	4	2.5	-0.0	1.03	0.87	2.4	51.3	-21	0.25	0.16																	
13MAR89.AW	15		2.5	0.01	1.12	0.84	2.1	49.6	-32	0.47	-0.63																	
13MAR89.AX	H	1										-0.5	5.47	0.28	1.87	54.3	-20	0.26	0.25	1								
13MAR89.AY	H											-0.0	5.31	0.3	2.18	44.3	-24	0.35	0.03	1								
13MAR89.AZ	B	4										-0.4	6.62	0.38	1.73	42.2	-20	0.47	0.03	3								
13MAR89.BA	B											-0.3	6.43	0.35	1.72	41.6	-25	0.61	-0.38	3								
13MAR89.BB	F	4										-0.4	5.85	0.24	1.62	58.3	-20	0.41	-0.2	1.3								
13MAR89.BC	F											-0.4	6.56	0.26	1.39	58.3	-20	0.53	-0.29	1.3								
13MAR89.BD	G	2										-0.8	5.95	0.19	1.86	45.1	-23	0.39	0.1	1.8								
13MAR89.BE	G											-0.4	5.6	0.18	1.79	57.6	-17	0.4	-0.26	1.8								

TABLE B-4. (CONTINUED)

PILOT M

								PITCH LOOP								ROLL LOOP								SPEED LOOP			
RUN	CASE	HQR	Kc	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	Kc	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA
13MAR89.BF	1 A	3	4.1	0.07	1.1	0.64	1.97	44.6	-35	0.26	0.5	-1.0	5.86	0.2	1.6	75.2	-14	0.3	-0.36	1.05								
13MAR89.BG	1 A		4.5	0.02	0.94	0.63	2.47	38.0	-29	0.18	1.12	-1.5	5.6	0.21	1.57	68.4	-22	0.32	-0.22	1.05								
13MAR89.BH	1 A		4.5	0.09	1.05	0.63	2.17	33.6	-33	0.3	0.69	-1.0	5.42	0.22	2.14	59.8	-20	0.31	-0.33	1.05								
13MAR89.BI	2 H	3	4	-0.0	0.99	0.47	2.89	40.5	-19	0.21	0.61	-1.5	6.5	0.26	1.45	58.5	-21	0.45	-0.2	1								
13MAR89.BJ	2 H		4	-0.0	1	0.46	2.17	49.3	-40	0.27	0.24	-0.6	6.12	0.24	1.55	57.4	-19	0.37	-0.05	1								
13MAR89.BK	2 B	5	3	-0.0	1.14	0.56	2.29	46.3	-35	0.59	-1.34	-0.2	8.63	0.41	1.55	34.5	-22	0.72	-0.3	2.5								
13MAR89.BL	2 B		3.75	0.03	1.03	0.5	2.68	37.3	-19	0.16	1.25	0.34	8.42	0.46	1.72	30.8	-15	0.58	0.02	2.5								
13MAR89.BM	2 H	2	4	-0.0	0.07	0.03	NO FF					-0.9	6.12	0.33	1.52	67.2	-14	0.34	-0.21	0.9								
13MAR89.BN	2 H		4	-0.0	0.09	0.04	NO FF					-0.6	6.06	0.23	1.21	70.2	-18	0.35	-0.13	0.9								
13MAR89.BO	2 C	7	4.6	0	0.97	0.43	2.38	45.7	-57	0.29	0.17	-1.4	9.37	0.51	1.35	39.0	-16	0.72	-0.21	1.9								
13MAR89.BP	2 C		4.6	-0.0	1.05	0.43	2.2	54.4	-50	0.31	-0.18	-0.7	9.16	0.56	1.44	39.9	-19	0.7	-0.26	1.9								
13MAR89.BQ	5 H	6	2.7	-0.1	1.2	0.53	2.5	41.4	-15	0.13	1.31	-0.7	6.16	0.29	1.26	78.5	-21	0.37	-0.35	1								
13MAR89.BR	5 H		2.7	0.03	1.16	0.53	2.78	43.0	-25	0.18	0.83	-0.6	6.33	0.29	1.56	67.8	-15	0.28	-0.09	1								
13MAR89.BS	5 H		2.7	-0.2	1.33	0.56	2.21	44.7	-30	0.39	-0.18	-2.2	6.7	0.28	1.34	66.0	-13	0.41	-0.22	1								
13MAR89.BT	5 B	6	2.7	-0.2	1.4	0.49	2.06	61.9	-33	0.58	-1.5	-0.8	7.92	0.4	1.51	40.5	-25	0.7	-0.35	2.5								
13MAR89.BU	5 B		2.7	0.01	1.15	0.49	2.49	47.3	-22	0.2	0.6	-1.9	7.91	0.37	1.47	49.4	-30	0.84	-0.8	2.5								
13MAR89.BV	5 H	5	3	0.05	1.19	0.5	2.21	42.2	-27	0.4	-0.14	-0.3	0.65	0.03	NO FF					1								
13MAR89.BW	5 H		3	0.17	1.13	0.48	2.18	48.5	-33	0.35	-0.09	-0.5	1.45	0.1	NO FF					1								
13MAR89.BX	5 C	7	3	0.17	1.14	0.47	2.58	52.5	-18	0.18	0.42	-1.2	9.45	0.53	1.53	37.4	-18	0.8	-0.53	2								
13MAR89.BY	5 C		3	0.13	1.16	0.47	2.75	37.2	-21	0.16	1.25	-1.9	9.16	0.47	1.27	39.5	-18	0.59	0.07	2								
13MAR89.BZ	6 H	5	1.9	-0.0	1.51	0.75	1.72	49.0	-32	0.38	0.07	1.84	6.83	0.24	0.83	84.4	-13	0.3	-0.14	1								
13MAR89.CA	6 H		1.9	0.11	1.6	0.75	1.69	47.5	-25	0.37	0.15	1.05	7.12	0.22	0.94	93.8	-16	0.48	-0.5	1								
13MAR89.CB	6 H		2.2	-0.0	1.55	0.67	1.77	42.5	-43	0.37	0.26	1.56	7.37	0.15	0.53	-52.	-15	-7.0	3.28	1								
13MAR89.CC	6 H		2.5	-0.1	1.5	0.61	1.81	37.4	-35	0.54	-0.17	1.24	7.37	0.21	0.92	68.3	-16	0.33	0.04	1								
13MAR89.CD	6 B	7	2.5	0.08	1.7	0.61	1.81	38.2	-23	0.51	-0.09	1.15	8.36	0.29	1.27	30.5	-35	0.69	0.09	2.5								
13MAR89.CE	6 B		2.5	-0.2	1.79	0.6	1.65	43.5	-32	0.55	-0.21	-0.5	9.81	0.35	1.28	32.0	-23	0.75	-0.05	2.5								
13MAR89.CF	4 H	4	3.75	-0.0	1.37	0.56	2.11	22.9	-35	0.43	0.5	-0.4	6.45	0.25	0.77	102.	-10	0.38	-0.4	1								
13MAR89.CG	4 H		3.75	0.07	1.39	0.53	1.94	28.7	-28	0.35	0.69	-0.5	6.44	0.19	1.11	76.7	-17	0.27	-0.1	1								

NO FF – no disturbance input but axis <u>not</u> fixed.

TABLE B-4. (CONTINUED)

PILOT M

			PITCH LOOP										ROLL LOOP									SPEED LOOP							
RUN	CASE	HQR	Kc	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	Kc	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA
14MAR89.AE	2	2	3.3	0.03	1.06	0.55	2.34	40.9	-23	0.27	0.49																	
14MAR89.AF	2		4	0.06	0.94	0.45	2.62	34.9	-20	0.2	1.1																	
14MAR89.AG	5	5	2.6	0.15	1.19	0.56	1.8	56.7	-31	0.3	0.05																	
14MAR89.AH	5		2.6	0	1.24	0.57	1.79	51.4	-29	0.28	0.26																	
14MAR89.AI	4	4	4.5	0.12	1.37	0.45	1.91	26.6	-30	0.4	0.58																	
14MAR89.AJ	4		4.5	0	1.32	0.42	1.81	35.8	-27	0.37	0.44																	
14MAR89.AK	H	2										-0.1	5.53	0.21	1.56	59.0	-21	0.42	-0.22	1.1								
14MAR89.AL	H											-0.2	5.18	0.24	2	50.9	-22	0.44	-0.44	1.1								
14MAR89.AM	B	4										-0.1	6.57	0.35	1.71	40.0	-27	0.63	-0.37	3.2								
14MAR89.AN	B											-0.6	6.07	0.33	1.94	34.1	-32	0.45	0.17	3.2								
14MAR89.AO	1	2																			-0.0	0.31	7.58	150.	********************			
14MAR89.AP	1																				-0.0	0.25	3.84	7.56	62.9	-11	0.24	0.01
14MAR89.AQ	2	1																			-0.0	0.17	1.73	1.5	75.8	-34	0.18	0.29
14MAR89.AR	6	1																			-0.0	0.24	1.6	2.23	6.21	-20	1.13	0.18
14MAR89.AS	2 H	4	4	-0.1	1.08	0.45	2.21	36.7	-46	0.39	0.09	-0.3	6.22	0.26	1.22	72.2	-18	0.37	-0.21	0.9								
14MAR89.AT	2 H		4.5	0.06	1.02	0.42	2.3	34.3	-43	0.29	0.7	-1	6.49	0.25	1.46	76.2	-19	0.28	-0.26	1.2								
14MAR89.AU	2 H		4.5	-0.1	0.97	0.41	2.36	37.9	-38	0.26	0.68	-1.2	6.26	0.23	1.43	64.9	-18	0.4	-0.23	1.2								
14MAR89.AV	2 B	5	4.5	-0.1	1.05	0.38	2.38	47.3	-38	0.27	0.24	1.46	8.16	0.41	1.5	38.1	-20	0.66	-0.21	2.5								
14MAR89.AW	2 B		4.5	-0.1	1.03	0.4	2.56	42.9	-24	0.19	0.83	0.62	7.84	0.44	1.63	42.8	-25	0.76	-0.71	2.5								
14MAR89.AX	5 H	5.5	2.7	-0.0	1.21	0.51	2.25	48.2	-26	0.34	-0.13	-0.1	5.82	0.23	1.48	69.6	-19	0.27	-0.1	1								
14MAR89.AY	5 H		2.7	0.1	1.11	0.51	2.34	45.1	-38	0.37	-0.19	0.24	6.94	0.21	1.02	70.9	-14	0.41	-0.13	1								
14MAR89.AZ	5 B	7	2.7	-0.1	1.22	0.49	2.11	57.8	-39	0.39	-0.56	-0.4	8.69	0.36	1.25	45.8	-19	0.73	-0.26	2.5								
14MAR89.BA	5 B		2.7	-0.0	1.2	0.51	2.65	40.7	-28	0.1	1.51	-1.5	8.21	0.28	1.29	57.4	-26	0.88	-0.78	2.5								
14MAR89.BB	2 1	3	4.2	0.01	1.03	0.46	2.55	45.5	-25	0.23	0.47										0.21	0.95	7.05	0.54	98.9	-39	0.43	-0.21
14MAR89.BC	2 1		4.2	0.04	1.16	0.45	2.13	39.8	-27	0.39	0.05										0.18	1.05	7.26	0.94	45.5	-2	1.1	-0.2
14MAR89.BD	2 1		4.2	-0.1	1.14	0.44	2.07	36	-36	0.36	0.35										0.13	0.85	6.78	.49	-4.39	-39	16.9	-1.6
14MAR89.BE	4 1	4	4.2	-0.0	1.46	0.49	2.02	29.7	-22	0.39	0.49										-0.1	1	6.97	.47	-87.8	-27	17.2	-1.59
14MAR89.BF	4 1		4.2	-0.0	1.4	0.46	1.83	35.0	-34	0.37	0.45										0.2	0.99	6.69	0.4	118.	-48	-1.0	-0.02
14MAR89.BG	2 6	3	4.2	-0.0	1.12	0.4	2.11	47.2	-34	0.18	0.72										0.13	0.89	2.31	0.76	6.96	-51	2.43	-0.28
14MAR89.BH	2 6		4.2	-0.0	1.1	0.41	2.11	43.2	-34	0.35	0.14										0.11	0.78	2.25	0.91	32.2	-28	0.75	0.37
14MAR89.BI	5 1	5	2.7	-0.0	1.35	0.54	1.64	54.7	-23	0.35	0.04										0.06	0.84	7.01	0.47	126.	-35	-2	0.15
14MAR89.BJ	5 1		2.7	0.01	1.27	0.55	1.82	52.3	-30	0.27	0.25										0.14	0.74	7.26	0.48	90.8	-37	0.57	-0.14
14MAR89.BK	2 2	3	4	-0.0	1.13	0.42	1.87	39.1	-36	0.39	0.23										0.07	0.55	2.08	1.01	13.8	-41	1.32	0.14
14MAR89.BL	2 2		4	-0.0	1.11	0.43	2.01	42.5	-34	0.32	-0.73										0.08	0.67	1.96	0.82	27.6	-35	1.14	0.16
14MAR89.BM	5 2	5	2.7	0.13	1.24	0.49	1.91	69.7	-23	0.33	-0.56										0.11	0.66	2.11	0.87	21.6	-34	1.17	0.21
14MAR89.BN	5 2		2.7	-0.0	1.3	0.53	1.91	51.4	-23	0.31	0.12										0.02	0.56	1.94	0.72	33.3	-82	1.2	0.1
14MAR89.BO	5 6	5	2.7	-0.0	1.29	0.51	1.78	55.6	-23	0.36	-0.13										0.22	0.81	2.7	0.89	12.8	-41	1.32	0.23
14MAR89.BP	5 6		2.7	-0.0	1.1	0.53	2.04	53.1	-33	0.31	-0.01										0.17	0.66	2.19	0.87	42.8	-43	0.24	0.59

TABLE B-4. (CONTINUED)

PILOT M

RUN	CASE	HQR	Kc	PITCH LOOP EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	ROLL LOOP EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	Kc	SPEED LOOP EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA
14MAR89.BQ	H 2	3										0.71	6.21	0.32	1.67	53.6	-23	0.42	-0.13	1	0.04	0.42	1.93	46.5	-89.	-5	1.32	0.19
14MAR89.BR	H 2											-0.3	5.75	0.31	1.65	54.9	-24	0.49	-0.34	1	0.05	0.45	1.86	0.77	87.6	-52	-0.5	0.38
14MAR89.BS	B 1	4										0.12	7.08	0.46	1.87	28.6	-28	0.4	0.58	2.7	0.01	0.73	7.13	0.47	111.	24	0.73	-0.34
14MAR89.BT	B 1											-1.0	6.7	0.46	1.9	31.7	-30	0.45	0.27	2.7	0.16	0.71	7.07	0.00	689.	1	1.02	-0.3
14MAR89.BU	B 6	4										-0.1	5.96	0.46	2.08	48.1	-23	0.48	-0.6	2.8	0.06	0.46	1.99	1.23	-17.	-34	1.74	0.16
14MAR89.BV	B 6											-0.1	6.63	0.49	2.06	49.5	-21	0.37	-0.15	2.8	0.05	0.38	1.83	26.8	83.6	-7	1.73	0.04
14MAR89.BW	H 1	3										0.12	5.27	0.31	1.84	55.4	-25	0.34	-0.03	1	0.13	0.66	7.12	0.13	186.	6	0.71	-0.34
14MAR89.BX	H 1											-0.7	5.83	0.31	1.76	47.4	-20	0.45	-0.09	1	0.08	0.55	7.31	0.87	63.1	-22	1.31	-0.59
14MAR89.BY	B 2	4										0.73	7.21	0.46	1.66	41.2	-21	0.66	-0.43	2.5	0.11	0.33	1.87	0.84	61.1	-85	-0.1	0.58
14MAR89.BZ	B 2											0.21	6.17	0.47	1.97	40.4	-35	0.43	-0.02	2.5	0.05	0.36	1.93	1.05	25.5	-48	1.11	0.12
14MAR89.CA	2 H 1	4.5	4	-0.1	1.2	0.49	2.2	32.6	-35	0.55	-0.5	-0.8	6.4	0.34	1.51	68.6	-13	0.48	-0.54	0.9	0.06	0.91	6.95	0.41	124.	10	2.26	-0.63
14MAR89.CB	2 H 1		4	0.05	1.03	0.47	2.28	35.2	-41	0.37	0.23	-0.7	6.03	0.32	1.51	58.3	-23	0.49	-0.31	0.9	-0.0	0.89	7.12	0.61	85.6	-44	0.21	-0.03
14MAR89.CC	2 H 1		4	-0.2	1.32	0.48	2.07	31.1	-32	0.32	0.7	-0.3	6.23	0.3	1.32	80.3	-22	0.22	-0.17	0.9	-0.0	0.81	7.5	0.3	95.0	25	0.91	-0.09
14MAR89.CD	2 H 6	4.5	4	-0.1	1.09	0.45	2.17	38.4	-47	0.42	-0.05	-0.1	6.56	0.3	1.57	60.5	-9	0.36	-0.12	0.9	0.08	1.22	2.88	1.41	-33.	-11	1.91	0.11
14MAR89.CE	2 H 6		4	-0.1	1.09	0.43	2.06	38.3	-42	0.31	0.5	-0.9	6.24	0.24	1.28	64.4	-24	0.3	0.03	0.9	0.01	0.93	2.45	0.77	56.1	-30	-0.4	0.75
14MAR89.CF	2 B 1	6	4.5	-0.0	1.14	0.41	2.6	34.5	-29	0.2	1.1	0.51	7.16	0.43	1.51	43.6	-37	0.54	-0.08	2.5	-0.1	0.96	6.54	0.46	118.	-27	-0.6	-0.09
14MAR89.CG	2 B 1		4.5	-0.1	1.1	0.39	2.23	43.9	-35	0.34	0.09	-0.8	7.23	0.35	1.52	38.9	-29	0.6	-0.11	2.5	0.14	0.87	7.08	0.20	945.	5	15.9	-3.9
14MAR89.CH	4 H 1	4	4.5	-0.0	1.37	0.43	1.91	32.5	-37	0.26	0.89	-0.5	6.05	0.25	1.41	77.7	-24	0.39	-0.49	1.1	-0.1	0.93	7.05	0.9	72.5	-14	0.39	-0.03
14MAR89.CI	4 H 1		4.5	-0.1	1.41	0.46	1.97	33.2	-28	0.34	0.59	-0.3	5.88	0.23	1.32	71.5	-22	0.41	-0.31	1.1	-0.0	0.93	6.82	0.4	140.	19	2.8	-0.79
14MAR89.CJ	2 B 6	5	4.5	-0.0	1.11	0.37	2.13	47.0	-31	0.34	0.01	0.53	7.96	0.36	1.16	61.7	-16	0.69	-0.4	2.5	0.21	1.19	3.07	0.63	-51.	-11	2.06	0.08
14MAR89.CK	2 B 6		4.5	-0.0	1	0.37	2.32	46.7	-37	0.38	-0.29	-1.5	7.46	0.37	1.47	47.0	-45	0.69	-0.44	2.5	-0.0	1.09	2.8	1.04	7.11	-17	1.3	0.31
14MAR89.CL	5 H 6	6	2.7	-0.1	1.36	0.49	1.82	68.7	-23	0.3	-0.34	-0.6	6.27	0.25	1	91.4	-16	0.25	-0.28	1	-0.1	1.23	3.01	0.96	-15.	-21	2.11	-0.05
14MAR89.CM	5 H 6		3	-0.1	1.25	0.43	1.81	67.8	-29	0.35	-0.47	-0.9	6.24	0.22	0.98	77.2	-20	0.34	-0.13	1	0.13	1.33	3.16	0.7	18.1	-56	2.53	-0.36
14MAR89.CN	5 H 6		3	-0.1	1.17	0.44	1.95	58.6	-36	0.37	-0.36	-1.1	6.21	0.22	1.05	82.2	-22	0.35	-0.26	1	0.03	0.88	2.44	0.84	-83.	-51	4.55	-0.59
14MAR89.CO	5 H 1	6	2.7	0.11	1.28	0.51	1.87	48.5	-38	0.53	-0.55	-0.7	6.28	0.22	1.21	70.4	-18	0.53	-0.39	1	-0.0	0.98	6.67	0.4	110.	-44	-1.8	0.164
14MAR89.CP	5 H 1		3	0.08	1.17	0.49	2.15	43.3	-35	0.32	0.25	-0.8	7.19	0.22	0.97	70.2	-14	0.44	-0.12	1	0.09	1.28	6.78	0.38	93.3	-63	-0.3	0.03
14MAR89.CQ	5 H 1		3	-0.0	1.16	0.47	2.04	54.5	-41	0.2	0.41	-0.2	6.5	0.21	1.16	73.3	-20	0.45	-0.31	1	0.04	0.99	6.99	0.59	82.9	-18	0.24	-0.01

TABLE B-4. (CONTINUED)

PILOT H

			PITCH LOOP									ROLL LOOP								
RUN	CASE	HQR	Kc	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	Kc
15MAR89.AA	1	2	3	0	1.13	0.87	1.95	63.1	-21	0.22	0.05									
15MAR89.AB	1		3	0.03	1.02	0.92	2.53	51.0	-19	0.25	0.1									
15MAR89.AC	2	2	1.5	-0.0	1.15	1.12	2.19	71.1	-13	0.09	0.25									
15MAR89.AD	2		1.5	0	1.07	1.22	3.05	49.0	-9	0.21	0.17									
15MAR89.AE	4	4	1.5	0.03	1.55	1.18	1.42	69.2	-6	0.3	-0.08									
15MAR89.AF	4		1.5	-0.0	1.52	1.27	1.72	66.1	-3	0.36	-0.37									
15MAR89.AG	4		2	0.14	1.46	0.88	1.62	69.8	-15	0.24	-0.08									
15MAR89.AH	6	6	1.25	-0.0	1.98	0.81	0.63	76.7	-24	0.21	0.06									
15MAR89.AI	6		1.25	0.05	1.98	0.82	0.65	84.2	-18	0.14	0									
15MAR89.AJ	H	2										-0.5	6.32	0.37	1.86	46.3	-12	0.31	0.34	1
15MAR89.AK	H											0.34	5.79	0.34	2.07	41.2	-18	0.27	0.54	1
15MAR89.AL	B	3										-0.2	8.3	0.78	1.78	29.0	-34	0.66	-0.21	2
15MAR89.AM	B											-0.4	7.98	0.72	1.89	25.5	-26	0.43	0.55	2
15MAR89.AN	C	4										-3.0	9.52	0.81	1.3	23.5	-29	0.74	0.12	1
15MAR89.AO	C											0.39	8.96	0.93	1.3	32.7	-21	0.65	0.1	1
15MAR89.AP	2 H	3	1.5	0.01	1.34	1.02	1.4	75.2	-12	0.31	-0.24	1.15	7.4	0.45	1.42	70.4	-22	0.36	-0.26	1
15MAR89.AQ	2 H		1.5	0.1	1.33	1.07	1.66	58.4	-27	0.3	0.07	0.66	10.1	0.58	1.09	59.7	-22	0.46	-0.03	1
15MAR89.AR	2 B	5	1.5	0.27	1.32	1.04	1.51	71.2	-21	0.28	-0.16	1.21	11.9	0.89	1.69	25.9	-21	0.54	0.3	2
15MAR89.AS	2 B		1.5	0.17	1.37	1	1.38	84.6	-17	0	0.13	2.82	12.1	1.04	1.81	25.2	-14	0.48	0.47	
15MAR89.AT	4 H	3	1.5	0.26	1.78	1.04	1.07	67.9	-13	0.39	-0.05	-0.3	8.62	0.45	1.24	78	-28	0.17	-0.03	1
15MAR89.AU	4 H		1.5	0.06	1.52	1	1.2	70.8	-18	0.22	0.08	2.17	9.24	0.4	0.84	61.3	-29	-0.0	0.44	1
15MAR89.AV	6 H	7	1.25	0.34	2.07	0.79	0.58	74.7	-19	0.19	0.09	-1.4	8.27	0.16	0.55	86.0	-5	0.27	-0.04	1
15MAR89.AW	6 H		1.25	-0.0	1.95	0.85	0.68	76.8	-20	0.16	0.07	1.88	8.92	0.22	0.9	76.4	-20	0.76	-0.44	1
15MAR89.AX	4 B	5.5	1.25	0.25	1.69	1.17	1.06	68.4	-17	0.44	-0.11	-2.5	9.65	0.43	1.02	46.8	-18	0.69	-0.03	2
15MAR89.AY	4 B		1.25	0.16	1.62	1.25	1.19	68.2	-16	0.3	0.02	0.48	10.0	0.45	1.23	28.1	-33	0.68	0.17	2
15MAR89.AZ	4 H	3	1.5	0.19	1.5	1.17	1.63	51.8	-17	0.41	-0.05	0.12	9.03	0.45	0.88	71.9	-30	0.07	0.2	1
15MAR89.BA	4 H		1.5	0.24	1.44	1.11	1.58	52.2	-21	0.31	0.24	0.17	7.98	0.37	0.85	100.	-17	0.54	-0.55	1
15MAR89.BB	2	2.5	1.5	-0.0	1.27	1.08	2.01	54.5	-13	0.36	-0.26									
15MAR89.BC	2		1.5	-0.0	1.22	1.06	1.99	57.4	-15	0.29	-0.05									
15MAR89.BD	14	2	1.5	0.08	1.16	1.33	1.95	78.8	-34	0.36	-1									
15MAR89.BE	14		1.5	-0.0	1.17	1.34	2.04	78.2	-14	0.17	-0.3									
15MAR89.BF	15	3	1.5	-0.0	1.28	1.28	1.83	69.3	-12	0.44	-0.83									
15MAR89.BG	15		1.5	-0.0	1.32	1.32	1.96	68.6	-20	0.37	-0.73									
15MAR89.BH	2 C	6	1.5	0.04	1.56	0.86	1.07	82.7	-11	0.17	-0.06	-1.2	11.1	0.56	1.11	65.7	-22	1.05	-0.87	1.5
15MAR89.BI	2 C		1.5	-0.0	1.54	0.94	1.19	82.1	-23	0.42	-0.44	-0.0	11.5	0.61	1.19	29.2	-35	0.79	0.02	1.5
15MAR89.BJ	6 B	8	1.5	-0.0	1.98	0.71	0.67	78.9	-19	0.32	-0.02	3.25	12.4	0.34	0.93	28.8	-28	1.01	0.02	1.5
15MAR89.BK	6 B		1.5	-0.1	2.15	0.68	0.56	76.5	-16	0.35	0.02	4.1	13.2	0.35	0.8	55.4	-27	1.01	-0.21	1.5

TABLE B-4. (CONTINUED)

PILOT H

			PITCH LOOP									ROLL LOOP								
RUN	CASE	HQR	Kc	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	Kc
16MAR39.AA	1	2	2	-0.0	1.07	1.39	2.3	38.9	-25	0.39	0									
16MAR39.AB	1		2	-0.0	1.05	1.37	2.53	37.4	-23	0.23	0.78									
16MAR39.AC	4	3	2	-0.0	1.42	0.86	1.39	66.9	-28	0.32	-0.07									
16MAR39.AD	4		2	-0.0	1.45	0.86	1.75	56.3	-11	0.37	-0.13									
16MAR39.AE	5	5	1	0.19	1.7	1.12	0.85	80.1	-19	0.24	-0.03									
16MAR39.AF	5		1	0.02	1.41	1.21	1.34	82.1	-12	0.12	-0.03									
16MAR39.AG	H	2										0.84	5.95	0.43	2.36	42.4	-22	0.34	0.02	1
16MAR39.AH	H											0.37	5.78	0.43	2.14	53.4	-6	0.22	0.33	1
16MAR39.AI	F	3										-0.0	7.48	0.47	1.9	35.5	-14	0.47	0.08	1
16MAR39.AJ	F											0.1	7.26	0.45	1.67	49.7	-19	0.38	0.08	1
16MAR39.AK	C	4										0.2	9.84	0.7	1.52	25.0	-29	0.68	0.05	1.5
16MAR39.AL	C											0.07	9.23	0.85	1.68	26.8	-29	0.66	-0.05	1.5
16MAR39.AM	G	2										-0.5	5.94	0.35	1.42	60.2	-16	0.4	-0.12	0.75
16MAR39.AN	G											0.02	6.62	0.43	1.5	49.6	-20	0.45	-0.02	0.75
16MAR39.AO	1 H	3	2.25	-0.1	1.25	1.11	1.73	45.9	-24	0.36	0.2	-2.1	7.48	0.39	0.99	68.0	-14	0.41	-0.07	0.75
16MAR39.AP	1 H		2.25	0.06	1.23	1.04	1.65	49.4	-22	0.31	0.28	-0.2	7.49	0.45	1.42	51.6	-18	0.52	-0.17	0.75
16MAR39.AQ	4 C	5	2.25	0.02	1.62	0.74	1.36	58.2	-15	0.5	-0.18	-3.3	10.0	0.51	0.83	28.5	-32	0.84	0.26	0.75
16MAR39.AR	4 C		2.25	0.06	1.66	0.68	1.14	66.7	-15	0.38	-0.04	-2.6	11.5	0.41	0.56	64.5	-21	2.01	-0.4	0.75
16MAR39.AS	5 H	5	1.25	0.08	1.56	0.89	0.91	85.2	-16	0.04	0.04	-1.8	7.85	0.33	1.17	43.3	-29	0.55	0.11	0.75
16MAR39.AT	5 H		1.25	0.02	1.54	0.9	0.99	90.1	-17	-0.1	0.11	-1.2	7.04	0.39	1.46	48.8	-23	0.46	0	0.75
16MAR39.AU	5 C	6	1.25	0.2	1.71	0.83	0.81	83.0	-21	0.27	-0.08	-5.8	13.5	0.57	0.92	16.6	-25	1.1	0.15	1
16MAR39.AV	5 C		1.25	0.2	1.63	0.8	0.79	91.8	-19	0.03	-0.04	-1.9	9.94	0.48	1.24	-11.	-40	1.2	0.15	1
16MAR39.AW	2	2.5	1.5	0.04	1.2	1.1	2.06	49.3	-24	0.29	0.17									
16MAR39.AX	2		1.5	0.1	1.12	1.05	2.2	54.4	-16	0.29	-0.09									
16MAR39.AY	9	2	1	-0.0	1.07	1.55	1.98	57.2	-24	0.32	-0.14									
16MAR39.AZ	9		1	-0.1	1.3	1.48	1.61	68.8	-26	0.29	-0.17									
16MAR39.BA	7	3	2	0.07	1.52	1.26	1.64	38.0	-28	0.56	-0.07									
16MAR39.BB	7		2	0.01	1.49	1.35	1.75	38.4	-20	0.55	-0.15									
16MAR39.BC	13	3	1	0.18	1.34	0.77	2.01	65.1	-13	0.42	-0.85									
16MAR39.BD	13		1	0.02	1.27	0.81	1.97	60.5	-17	0.51	-0.99									
16MAR39.BE	H	2										1.29	6.38	0.3	1.79	53.0	-14	0.38	-0.05	1
16MAR39.BF	H											2.26	6.1	0.33	1.74	50.0	-24	0.4	-0.02	1
16MAR39.BG	I	4										1.74	7.38	0.3	1.31	60.2	-13	0.47	-0.18	1
16MAR39.BH	I											1.65	7.78	0.31	1.08	60.6	-16	0.37	0.07	1
16MAR39.BI	7 H	4	2.5	0.33	1.72	0.92	1.35	44.1	-21	0.71	-0.23	-0.0	7.43	0.36	0.7	100.	-42	0.35	-0.3	1
16MAR39.BJ	7 H		2.5	0.27	1.53	1	1.52	42.4	-26	0.49	0.12	-1	7.7	0.31	0.84	84.9	-23	0.1	-0.01	1
16MAR39.BK	9 H	3	1	0.03	1.3	1.33	1.69	81.6	-20	0.16	-0.21	-0.2	8.76	0.33	1.35	46.1	-33	0.57	-0.09	1
16MAR39.BL	9 H		1.5	0.18	1.23	0.94	1.9	78.0	-18	0.05	0.2	0.25	7.78	0.33	1.51	52.0	-21	0.57	-0.34	1
16MAR39.BM	2 I	4.5	1.5	0.33	1.41	0.96	1.47	74.0	-22	0.36	-0.38	-2.2	8.94	0.41	1.4	56.6	-30	0.33	0.1	1
16MAR39.BN	2 I		2	0.33	1.42	0.71	1.35	83.4	-13	0.06	0.04	-0.7	8.04	0.29	1.04	58.9	-19	0.45	0.01	1
16MAR39.BO	13 H	3	1	0.24	1.19	0.81	2.47	54.3	-20	0.26	-0.04	-0.9	7.06	0.33	1.38	58.0	-27	0.48	-0.19	1
16MAR39.BP	13 H		1	0.23	1.25	0.8	2.39	55.0	-13	0.47	-1.2	-0.9	6.99	0.32	1.4	58.8	-26	0.48	-0.22	1

TABLE B-4. (CONTINUED)

PILOT H

			PITCH LOOP									ROLL LOOP							
RUN	CASE	HQR	Kc	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	Kc
16MAR89.BQ	1	2	3	0	1.18	1.02	2.11	50.5	-26	0.3	0.06									
16MAR89.BR	1		3	-0.0	1.02	1.07	2.38	48	-28	0.29	0.12									
16MAR89.BS	4	4	2	0.05	1.65	1.04	2.15	45.8	-10	0.35	0.02									
16MAR89.BT	4		2.5	-0.0	1.68	0.77	1.56	63.3	-14	0.32	-0.07									
16MAR89.BU	6	5.5	1.25	0.01	2.15	0.93	0.6	80.8	-14	-0.0	0.12									
16MAR89.BV	6		1.25	-0.0	2.17	0.92	0.68	85.2	-18	0.31	-0.09									
16MAR89.BW	A	2										1.32	5.52	0.23	1.54	61.3	-22	0.25		1
16MAR89.BX	A											0.06	6.62	0.24	1.35	58.9	-19	0.44	-0.1	1
16MAR89.BY	H	3										0.16	6.71	0.3	1.63	49.6	-17	0.38	0.1	1
16MAR89.BZ	H											1.07	6.62	0.26	1.43	64.1	-20	0.22	0.14	1
16MAR89.CA	C	5										1.18	8.44	0.35	1.23	23.1	-32	0.99	-0.1	2
16MAR89.CB	C											0.24	11.3	0.47	1.24	22.0	-22	0.92	-0.0	2
16MAR89.CC	C	3										0.69	4.01	0.28	1.19	15.6	-24	0.79	0.27	1.2
16MAR89.CD	C											-0.3	4.58	0.32	1.56	20.9	-31	0.53	0.49	1.2
16MAR89.CE	1 A	2	3	0.02	1.19	0.94	2.13	40.7	-22	0.35	0.18	-1.0	6.35	0.37	1.3	73.0	-29	0.17	0.06	0.75
16MAR89.CF	1 A		3	0.09	1.17	1	2.28	36.8	-22	0.37	0.18	-0.6	7.85	0.47	1.31	58.7	-21	0.25	0.23	0.75
16MAR89.CG	4 H	5	1.5	0.16	1.63	1.2	1.45	64.4	-11	0.43	-0.26	0.16	13.1	0.61	1.41	44.2	-23	0.75	-0.4	1
16MAR89.CH	4 H		1.5	0.1	1.59	1.16	1.56	63.3	-9	0.4	-0.26	-1.6	11.7	0.66	1.73	28.0	-15	0.59	0.07	1
16MAR89.CI	6 C	7.5	1.7	0.25	2.13	0.61	0.51	86.2	-14	-0.0	0.04	-0.5	15.4	0.68	1.24	6.68	-28	1.46	-0.6	1.25
16MAR89.CJ	6 C		1.7	0.21	2.03	0.66	0.67	86.7	-16	0.4	-0.14	-0.0	12.5	0.5	0.89	20.4	-50	0.65	0.47	1.25
16MAR89.CM	2 H	4	2	0.09	1.16	0.93	3.19	42.0	-20	0.29	-0.35	-1.2	9.73	0.63	1.72	48.6	-26	0.42	-0.0	1
16MAR89.CN	2 H		2	0.17	1.22	0.91	1.9	73.5	-22	0.19	-0.16	-1.0	9.43	0.64	1.94	49.5	-30	0.71	-1.3	1

TABLE B-4. (CONTINUED)

PILOT B

				PITCH LOOP								ROLL LOOP									SPEED LOOP							
RUN	CASE	HCR	Kc	EBAR	ESIG	CSIG	WC	PHL	SLOPE	TE	ALPHA	EBAR	ESIG	CSIG	WC	PHL	SLOPE	TE	ALPHA	Kc	EBAR	ESIG	CSIG	WC	PHL	SLOPE	TE	ALPHA
20MAR89.AA	2	2.5	2	0.04	0.97	0.91	2.63	47.0	-17	0.25	0.22																	
20MAR89.AB	2		2	0.05	1.02	0.94	2.77	37.5	-14	0.19	0.98																	
20MAR89.AC	4	4	2	0.04	1.43	1.07	2.03	[illegible]	-28	0.4	0.28																	
20MAR89.AD	4		2	0.08	1.44	1.07	2.05	[illegible]	-24	0.34	0.4																	
20MAR89.AE	1	1.5	2	0.03	1.04	1.47	2.28	35.5	-29	0.23	0.94																	
20MAR89.AF	1		2.5	-0.0	0.9	1.2	2.67	34.8	-21	0.17	1.32																	
20MAR89.AG	5	5.5	1.5	0	1.33	1	1.72	55.1	-24	0.29	0.16																	
20MAR89.AH	5		1.5	0.04	1.31	0.96	2.06	47.4	-25	0.38	-0.12																	
20MAR89.AI	13	2.5	1.5	0.07	0.95	0.68	2.92	34.0	-19	0.18	1.25																	
20MAR89.AJ	13		1.5	-0.0	0.94	0.67	3.16	38.4	-20	0.2	0.71																	
20MAR89.AK	6	6	1.5	0.1	1.82	1.15	1.56	38.9	-24	0.29	0.65																	
20MAR89.AL	6		1.75	0.06	1.85	1.02	1.9	34.3	-28	0.37	0.46																	
20MAR89.AM	6		1.75	-0.0	1.7	0.97	1.87	32.8	-34	0.38	0.49																	
20MAR89.AN	H	2.5										-0.0	7.74	0.48	1.97	33.9	-20	0.34	0.55	1								
20MAR89.AO	H											0.47	8.23	0.51	1.95	38.8	-7	0.44	0.05	1								
20MAR89.AP	I	2										0.25	8.54	0.5	1.87	36.3	-13	0.47	0.09	1								
20MAR89.AQ	I											0.08	7.4	0.36	2.01	28.2	-17	0.46	0.26	1								
20MAR89.AR	C	5										0.34	13.3	1.4	1.77	19.3	-27	0.6	0.3	1.25								
20MAR89.AS	C											0.05	11.8	1.23	1.67	20.7	-23	0.6	0.3	1.25								
20MAR89.AT	B	4										0.27	10.3	1.22	1.95	14	-21	0.55	0.44	1.25								
20MAR89.AU	B											0.25	9.89	1.26	2.12	5.93	-27	0.53	0.63	1.25								
20MAR89.AV	B											-1.2	10.3	1.47	2.14	7.59	-11	0.66	-0.03	1.25								
20MAR89.AW	C*	4.5										1.75	8.87	1.02	1.65	15.4	-16	0.67	0.24	1.25								
20MAR89.AX	C*											1.12	8.47	1.21	1.5	42.8	-8	0.6	-0.18	1.25								
20MAR89.AY	C*											-1.7	6.06	0.59	2.07	-1.2	-21	0.73	0.07	1.25								
20MAR89.AZ	C*											0.46	5.8	0.69	2.13	2.25	-15	0.58	0.54	1.25								
20MAR89.BA	2 H	5	1.75	0.35	1.35	0.93	1.39	56.3	-26	0.42	0.01	0.17	10.0	0.62	1.71	38.1	-31	0.42	0.28	1.25								
20MAR89.BB	2 H		1.75	0.14	1.31	0.89	1.46	62.1	[illegible]	0.38	-0.11	-0.5	10.9	0.5	1.6	48.5	[illegible]	0.46	-0.06	1.5								
20MAR89.BC	2 H		1.75	0.35	1.55	0.91	1.32	63.4	-17	0.21	0.25	-1.6	10.7	0.45	1.79	34.8	[illegible]	0.5	0.12	1.5								
20MAR89.BD	5 H	5.5	1.75	0.26	1.53	0.83	1.4	70.3	-23	0.2	0.09	-1.0	9.67	0.35	2.18	35.9	-16	0.46	-0.21	1.5								
20MAR89.BE	5 H		1.75	0.29	1.51	0.5	1.38	62.9	-19	0.34	0.01	-1.3	9.01	0.36	1.51	46.2	-20	0.45	0.01	1.5								
20MAR89.BF	4 I	[illegible]	2	0.31	1.66	0.93	1.43	39.2	-19	0.34	0.57	-0.9	10.2	0.56	1.41	48.0	-19	0.49	-0.02	1								
20MAR89.BG	4 I		2.3	0.6	1.55	0.81	1.61	46.7	-23	0.35	0.28	-1.2	10.3	0.54	1.5	41.4	-18	0.54	-0.01	1								
20MAR89.BH	5 C*	7	2.3	0.45	2.09	0.56	0.77	95.0	-32	-0.3	0.15	-2.1	20.3	1.6	1.26	6.69	-25	0.64	0.64	1								
20MAR89.BI	5 C*		2.3	0.34	1.76	0.61	1	81.8	-21	0.14	-0.01	-0.3	14.8	1.59	1.67	7.51	-38	0.67	0.46	1.15								
20MAR89.BJ	5 C*		2.3	0.44	1.85	0.64	1.54	73.8	-39	0.04	0.34	-0.6	13.5	1.38	1.65	11.8	-14	0.77	0.08	1.15								

TABLE B-4. (CONTINUED)

PILOT W

RUN	CASE	HQR	Kc	FITCH LOOP EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	ROLL LOOP EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	Kc
21MAR89.AF	1	2	4.5	0.05	1.06	0.64	2.1	50.2	-27	0.18	0.62									
21MAR89.AG	1		4.5	0.04	1.05	0.61	2.04	49.1	-22	0.25	0.37									
21MAR89.AH	2	3	2.8	0.08	1.08	0.66	2.48	53.9	-12	0.22	0.21									
21MAR89.AI	2		2.8	0.1	1.06	0.62	1.88	61.0	-31	0.16	0.35									
21MAR89.AJ	9	4	2.5	0.05	1.02	0.63	2.06	60.5	-28	0.24	0.01									
21MAR89.AK	9		2.5	0.01	1.07	0.63	2.04	70.1	-23	0.14	0.12									
21MAR89.AL	5	5	1.5	0.07	1.41	1.03	1.62	71.9	-27	0.17	0.05									
21MAR89.AM	5		1.5	-0.0	1.31	0.94	2.12	61.6	-16	0.44	-0.96									
21MAR89.AN	5		1.5	0.04	1.28	0.98	2.57	45.7	-20	0.3	-0.01									
21MAR89.AO	4	5	2.5	0.04	1.45	0.86	1.76	39.8	-26	0.27	0.64									
21MAR89.AP	4		2.5	0.08	1.5	0.84	1.79	35.7	-19	0.29	0.7									
21MAR89.AQ	A	3										0.2	5.62	0.27	1.93	57.0	-19	0.33	-0.15	1
21MAR89.AR	A											0.05	5.25	0.23	2.28	58.4	-14	0.15	0.44	1
21MAR89.AS	H	2										-0.1	6.1	0.31	1.61	58.1	-19	0.41	-0.21	1
21MAR89.AT	H											0.19	6.08	0.3	1.83	48.2	-23	0.37	0.09	1
21MAR89.AU	I	5										0.66	7.86	0.46	1.67	45.3	-19	0.39	0.18	1
21MAR89.AV	I											0.74	7.45	0.4	1.51	47.4	-25	0.39	0.17	1
21MAR89.AW	B	6										-0.0	7.89	0.68	1.77	35.5	-19	0.55	-0.05	2.8
21MAR89.AX	B											0.97	7.45	0.59	1.77	35.9	-43	0.54	-0.02	2.8
21MAR89.AY	B											-0.2	7.51	0.56	1.7	37.7	-16	0.47	0.16	3
21MAR89.AZ	1 A	2	4	0.09	0.99	0.7	2.26	47.3	-26	0.22	0.52	-0.0	5.87	0.23	1.59	56.4	-22	0.29	0.15	1
21MAR89.BA	2 H	3	2.8	0.27	1.11	0.63	2.6	55.4	-19	0.21	0.08	-0.0	7.04	0.29	1.62	44.5	-16	0.42	0.13	1
21MAR89.BB	2 H		2.8	0.11	1.11	0.61	2.09	63.0	-17	0.24	-0.11	-0.2	7.05	0.26	1.38	50.7	-17	0.42	0.07	1
21MAR89.BC	4 H	5	2.5	0	1.48	0.78	1.69	50.8	-24	0.34	0.16	1.04	6.93	0.26	1.3	48.4	-25	0.45	0.09	1
21MAR89.BD	4 H		2.5	0.2	1.41	0.79	1.7	46.2	-28	0.35	0.24	0.34	6.7	0.34	1.88	42.1	-19	0.5	-0.21	1
21MAR89.BE	2 B	6	2.8	0.12	1.12	0.68	2.1	60.3	-25	0.33	-0.38	1.39	9.88	0.66	1.85	21.3	-17	0.61	0.13	2.5
21MAR89.BF	2 B		2.8	0.09	1.06	0.65	2.09	67.5	-26	0.3	-0.51	0.75	10.1	0.71	2.08	16.0	-25	0.49	0.49	2.5
21MAR89.BG	5 H	6	1.8	0.14	1.25	0.77	2.05	68.7	-17	0.27	-0.39	0.72	6.7	0.38	1.71	55.9	-24	0.29	0.14	1
21MAR89.BH	5 H		1.8	0.06	1.23	0.77	2.77	45.9	-24	0.2	0.46	0.12	7.53	0.36	1.06	65.6	-11	0.41	-0.06	1

TABLE B-4. (CONCLUDED)

PILOT B

RUN	CASE	HQR	PITCH LOOP Kc	EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	ROLL LOOP EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA	Kc	SPEED LOOP EBAR	ESIG	CSIG	WC	PML	SLOPE	TE	ALPHA
21MAR89.BI	2 H	4.5	2	0.24	1.24	0.87	1.92	61.3	-20	0.09	0.61	0.13	9.46	0.66	2.17	38.9	-18	0.37	0.11	1								
21MAR89.BJ	2 H		2	0.24	1.16	0.87	1.96	48.9	-21	0.3	0.2	-0.1	9.43	0.59	2.09	28.4	-21	0.43	0.33	1.1								
21MAR89.BK	4 I	5	2	0.44	1.64	0.9	1.34	54.5	-23	0.33	0.24	0.28	10.7	0.62	1.52	37.0	-34	0.46	0.27	1.1								
21MAR89.BL	4 I		2.3	0.29	1.58	0.85	1.48	44.2	-20	0.35	0.39	-0.0	9.86	0.48	1.5	41.7	-26	0.62	-0.19	1.1								
21MAR89.BM	4 I		2.3	0.67	1.47	0.78	1.48	51.3	-20	0.33	0.26	-1.0	9.3	0.45	1.71	34.6	-30	0.59	-0.11	1.1								
21MAR89.BN	6	2																			0.01	0.95	2.19	1.33	9.32	-12	1.28	0.07
21MAR89.BO	6																				0.02	0.74	1.87	0.72	56.8	-74	-6.2	3.67
21MAR89.BP	2 6	2.5	2.3	0.24	1.48	0.75	1.71	54.6	-12	0.25	0.3										-0.3	1.84	3.09	0.56	-3.1	-91	3.39	-0.16
21MAR89.BQ	2 6		2.3	0.08	1.25	0.75	1.79	51.7	-30	0.26	0.33										0.13	0.73	2.23	0.18	669.	16	11.1	-2.4
21MAR89.BR	2 6		2.3	0.31	1.36	0.7	1.62	59.7	-27	0.11	0.54										0.09	1.06	2.92	0.19	249.	9	2.95	-0.71
21MAR89.BS	4 6	4	2.3	0.08	1.56	0.86	1.61	37.9	-24	0.28	0.69										0.43	1.09	2.54	1.58	-32.	-15	1.81	0.07
21MAR89.BT	4 6		2.3	0.1	1.54	0.8	1.58	48.0	-26	0.44	0.03										-0.5	0.81	1.65	0.49	87.5	-52	-0.3	0.12
21MAR89.BU	4 6		2.3	0.03	1.65	0.76	1.4	47.9	-21	0.37	0.29										-0.0	1.13	2.2	1.4	67.5	-10	0.34	0.07
21MAR89.BV	H 6	2.5										-0.2	6.75	0.24	1.29	60.9	-25	0.36	-0.01	1.1	-0.0	0.87	2.06	1.36	62.5	-19	0.36	0.29
21MAR89.BW	H 6											-0.4	7.76	0.26	1.36	45.9	-27	0.54	-0.04	1.1	-0.0	0.81	1.97	1.32	47.6	-11	0.61	0.24
21MAR89.BX	H 6											-1.0	7.14	0.27	1.39	45.9	-22	0.46	0.1	1.1	-0.0	0.86	1.97	0.6	72.8	-78	-1.4	0.7
21MAR89.CA	2 H 6	3.5	2.3	0.35	1.26	0.7	1.74	60.8	-20	0.18	0.3	-0.9	6.49	0.29	1.64	51.2	-25	0.37	0.07	1.1	-0.3	1.21	2.19	2.99	-89.	-3	1.92	-0.12
21MAR89.CB	2 H 6		2.3	0.42	1.27	0.72	1.86	58.9	-23	0.36	-0.28	-0.8	7.2	0.35	1.66	45.2	-35	0.42	0.09	1.1	-0.4	1.19	2.39	0.6	35.8	-29	1.91	-0.13
21MAR89.CC	4 H 6	5	2.3	0.45	1.4	0.79	1.63	49.5	-26	0.26	0.42	-0.4	6.74	0.34	1.79	48.4	-22	0.42	-0.05	1.1	-0.4	1.71	2.66	0.43	34.8	-38	0	0.4
21MAR89.CD	4 H 6		2.3	0.51	1.52	0.81	1.58	49.7	-25	0.35	0.2	-1.1	6.86	0.3	1.3	58.5	-25	0.28	0.18	1.1	-0.0	1.44	2.15	0.57	44.6	-31	1.8	-0.13
21MAR89.CE	4 H 6		2.3	0.31	1.42	0.78	1.69	52.5	-19	0.39	-0.04	-1.9	7.03	0.3	1.32	56.4	-28	0.31	0.17	1.1	-0.5	1.49	2.63	0.55	39.2	-34	2.26	-0.19

TABLE B-5. OPEN-LOOP DESCRIBING FUNCTION DATA (LAMARS)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (PITCH)

RUN	0.20		0.50		0.90		1.40		2.40		4.20		9.00	
14FEB89.AN	23.52	-106.3	17.92	-107.0	9.43	-116.5	4.36	-116.5	.48	-133.7	-4.13	-148.9	-6.35	-233.0
14FEB89.AO	24.54	-88.5	15.23	-116.7	9.06	-114.0	4.61	-121.4	-.96	-131.3	-4.62	-150.3	-6.64	-204.4
14FEB89.AP	16.19	-71.5	10.72	-104.5	5.34	-113.0	2.18	-116.0	-4.89	-132.3	-4.07	-160.4	-1.64	45.3
14FEB89.AQ	17.41	-86.8	9.06	-108.5	2.90	-103.2	.16	-113.5	-4.56	-131.8	-3.27	-150.9	-2.05	36.9
14FEB89.AR	8.59	-91.8	2.80	-94.4	-.66	-107.5	-3.16	-117.1	-5.38	-128.7	-6.71	-150.0	-10.29	6.4
14FEB89.AS	13.37	-88.8	3.69	-96.8	-.06	-105.6	-4.37	-113.6	-8.59	-154.0	-4.82	-139.3	-5.61	15.3
14FEB89.AZ	23.07	-124.3	14.65	-98.1	5.56	-115.9	.58	-129.9	-1.66	-126.4	-5.97	-168.9	-5.97	31.7
14FEB89.BA	15.84	-92.0	13.71	-76.8	4.27	-106.0	1.12	-122.2	-3.83	-135.7	-6.04	-157.9	-4.48	25.1
14FEB89.BB	19.71	-107.1	13.19	-121.8	7.48	-113.7	3.75	-114.4	-1.88	-127.1	-6.52	-148.1	-7.49	-189.9
14FEB89.BC	29.64	-125.3	15.61	-115.5	10.78	-121.7	4.09	-129.8	-1.65	-120.4	-4.95	-146.8	-5.73	-189.7
14FEB89.BD	12.28	-115.3	7.66	-107.9	1.76	-105.0	-.92	-111.8	-.84	-103.7	-2.33	-152.8	-1.41	51.9
14FEB89.BE	15.87	-107.3	6.43	-101.7	3.03	-111.9	.50	-101.3	-2.51	-119.9	-2.48	-152.8	-1.95	33.7
14FEB89.BF	13.04	-88.6	.34	-76.8	-5.13	-93.7	-2.64	-91.9	-7.73	-149.7	-7.93	-154.6	-6.51	-18.5
14FEB89.BG	6.59	-106.0	-1.37	-70.7	-6.20	-96.5	-3.77	-88.5	-6.36	-105.2	-6.63	-78.5	-3.29	28.3
14FEB89.BH	14.03	-82.1	3.95	-104.0	-1.22	-95.5	-3.66	-106.1	-6.42	-115.2	-4.58	-146.0	-4.32	32.6
14FEB89.BI	13.11	-122.3	7.68	-104.3	.46	-107.9	-3.97	-97.6	-5.64	-123.9	-5.54	-147.7	-.83	46.3
14FEB89.BJ	10.52	-108.8	5.50	-93.7	1.11	-107.2	-4.15	-96.5	-5.28	-130.3	-5.	50.4	-1.94	35.8
14FEB89.BK	25.73	-108.9	11.15	-94.5	5.15	-120.3	1.27	-110.1	-2.95	-127.6	-5.67	147.6	-9.10	-210.7
14FEB89.BL	17.31	-103.3	11.33	-105.8	4.71	-118.9	-.63	-113.5	-2.81	-113.4	-7.09	42.8	-8.50	-205.4
14FEB89.BM	16.39	-100.7	12.57	-109.8	5.02	-117.0	.69	-115.0	-3.45	-111.8	-6.37	41.9	-9.00	-202.1
14FEB89.BN	16.73	-95.0	10.45	-92.8	4.29	-104.3	.84	-108.8	-2.83	-129.3	-5.52	138.8	-7.93	-233.6
14FEB89.BO	17.11	-71.1	10.24	-88.8	4.52	-99.2	1.82	-103.8	-3.08	-119.6	-4.92	-146.1	-7.96	-237.2
14FEB89.BP	16.59	-101.8	7.99	-106.3	3.30	-109.3	-1.03	-117.1	-4.74	-129.2	-4.86	-159.1	-4.68	32.2
14FEB89.BQ	15.34	-98.7	7.71	-97.4	1.89	-108.4	-1.43	-115.2	-3.88	-127.4	-5.06	-159.0	-5.56	26.6
14FEB89.BR	5.67	-110.6	.77	-103.5	-4.58	-99.5	-6.25	-90.4	-10.78	-114.1	-6.69	-144.9	-9.75	12.0
14FEB89.BS	9.13	-86.5	1.32	-97.9	-3.73	-99.2	-5.54	-99.5	-7.01	-120.1	-6.58	-141.7	-9.61	-14.1

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (ROLL)

RUN	0.30		0.40		0.70		1.80		3.00		4.00		7.00	
14FEB89.AT	17.70	-90.7	14.77	-90.6	9.96	-109.6	.33	-118.6	-4.18	-137.5	-5.38	-148.2	-9.22	-182.9
14FEB89.AU	14.36	-86.9	14.34	-98.1	9.28	-94.5	-.60	-115.8	-5.02	-139.0	-7.90	-148.5	-9.88	-189.4
14FEB89.AV	18.29	-52.1	9.07	-48.7	7.19	-100.0	-3.13	-133.3	-7.41	-163.6	-9.18	-181.6	-13.41	-234.0
14FEB89.AW	14.31	-84.9	11.88	-94.0	9.08	-101.8	-.89	-128.5	-6.05	-157.1	-9.03	-180.2	-12.41	-233.5
14FEB89.AX	7.81	-79.9	13.16	-132.6	4.87	-128.8	-3.66	-160.9	-8.64	-202.7	-12.88	-222.8	-18.02	51.6
14FEB89.AY	14.01	-63.5	7.53	-117.5	4.16	-108.6	-1.87	-152.8	-6.03	-187.5	-7.58	-234.0	-17.83	45.4
14FEB89.BB	11.77	-114.0	11.01	-80.1	6.85	-95.3	-.91	-114.3	-2.35	-143.3	-7.02	-142.5	-7.34	-208.0
14FEB89.BC	14.33	-104.7	13.40	-106.1	5.17	-97.0	-.14	-121.1	-4.58	-141.9	-6.43	-155.8	-8.65	-205.2
14FEB89.BD	6.66	-69.4	5.77	-71.4	6.39	-119.6	-1.05	-123.4	-5.20	-164.6	-7.18	-187.5	-10.40	67.4
14FEB89.BE	13.58	-97.6	12.45	-86.3	7.47	-111.8	-.76	-135.5	-5.02	-166.6	-5.75	-191.4	-11.40	82.0
14FEB89.BF	15.13	-141.6	13.54	-114.7	8.00	-62.9	-4.36	-200.5	-10.75	-218.3	-18.20	-255.4	-18.95	-11.7
14FEB89.BG	9.06	-63.9	9.69	-101.3	7.57	-83.4	-5.80	-183.7	-10.12	-212.2	-27.28	87.0	-20.54	-6.3
14FEB89.BH	6.09	-91.5	8.95	-92.0	2.79	-102.5	-4.45	-130.5	-7.79	-161.1	-9.76	-192.6	-15.58	70.7
14FEB89.BI	6.87	-66.5	7.12	-79.2	.78	-90.1	-2.96	-113.9	-8.30	-172.1	-11.40	-177.9	-13.99	73.6
14FEB89.BJ	15.43	-53.4	4.86	-92.4	3.05	-98.5	-6.37	-130.4	-6.52	-163.0	-8.22	-200.0	-14.11	76.5
14FEB89.BT	13.98	-80.8	12.33	-65.6	12.20	-102.8	1.03	-127.3	-4.42	-168.1	-5.64	-178.5	-9.27	-246.3
14FEB89.BU	18.38	-89.3	12.93	-81.8	8.22	-106.2	.76	-127.6	-3.31	-153.4	-4.84	-174.9	-9.05	-242.0
14FEB89.BV	15.40	-77.4	13.26	-83.5	7.68	-97.3	-.41	-129.0	-4.38	-150.0	-5.87	-174.4	-9.02	-234.9
14FEB89.BW	16.94	-71.0	9.13	-76.8	5.51	-113.9	-2.68	-152.7	-7.62	-190.1	-9.57	-235.6	-16.74	51.4
14FEB89.BX	16.70	-10.3	15.55	-59.5	4.95	-113.6	-2.70	-148.4	-6.15	-190.3	-9.34	-231.0	-16.16	59.8

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (SPEED)

RUN	0.10		0.30		0.50		0.70	
14FEB89.AZ	13.76	.3	5.90	-151.8	-1.90	-116.5	-1.97	-156.9
14FEB89.BA	16.59	-144.3	11.85	-69.6	-8.55	-176.2	-1.41	-119.7
14FEB89.BI	16.54	-195.6	4.86	-135.9	3.90	-180.8	-1.26	-157.4
14FEB89.BJ	13.69	-173.3	10.21	-161.2	-1.87	-152.7	-5.72	-181.7

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (PITCH)

RUN	0.20		0.50		0.90		1.40		2.40		4.20		9.00	
15FEB89.AK	28.48	-121.7	13.13	-139.5	7.52	-104.1	4.39	-127.6	-1.23	-123.7	-5.69	-148.5	-5.42	-204.9
15FEB89.AL	18.27	-97.6	15.08	-113.1	8.50	-107.3	3.96	-103.8	-.60	-134.4	-4.97	-142.8	-6.15	-192.9
15FEB89.DA	19.71	-82.3	14.37	-102.7	8.02	-110.0	5.62	-104.3	-1.66	-126.0	-6.49	-143.7	-6.05	-197.3
15FEB89.DB	16.88	-117.9	6.40	-88.6	2.92	-100.8	-.68	-115.3	-3.36	-127.9	-3.69	-151.1	-1.46	64.3
15FEB89.DC	15.40	-119.2	6.98	-101.4	3.14	-99.4	.76	-101.9	-3.56	-132.0	-4.33	-153.0	.57	57.2
15FEB89.DD	12.21	-87.2	5.74	-97.5	2.56	-89.1	.25	-105.5	-4.01	-127.8	-3.90	-146.0	.64	66.1
15FEB89.DE	14.39	-92.8	7.17	-99.4	3.87	-85.3	.66	-110.2	-1.65	-129.1	-4.34	-147.9	2.12	56.8
15FEB89.DF	13.80	-71.7	8.48	-99.6	.34	-97.9	2.04	-106.4	-3.95	-130.1	-5.65	-154.9	-1.84	40.3
15FEB89.DG	15.08	-87.5	11.81	-96.0	3.93	-96.2	2.78	-100.7	-4.62	-124.6	-4.90	-149.3	-2.22	56.6

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (ROLL)

RUN	0.30		0.40		0.70		1.80		3.00		4.00		7.00	
15FEB89.AM	12.65	-79.9	9.87	-77.4	6.83	-99.2	-1.04	-125.9	-4.27	-153.4	-4.88	-172.2	-10.32	-238.0
15FEB89.AN	11.21	-61.3	13.62	-71.1	6.65	-106.6	-.92	-123.7	-4.28	-154.7	-6.69	-166.5	-9.91	-233.0
15FEB89.AO	11.21	-61.3	13.62	-71.1	6.65	-106.6	-.92	-123.7	-4.28	-15 .7	-6.69	-166.5	-9.91	-233.0
15FEB89.DA	9.57	-88.2	8.22	-80.3	4.19	-71.4	-2.96	-115.3	-3.35	-143.9	-6.62	-194.1	-9.21	82.9
15FEB89.DB	9.53	-25.7	8.95	-67.8	5.75	-100.4	-4.04	-108.5	-4.76	-160.6	-6.42	-195.2	-11.56	77.6
15FEB89.DC	18.98	-46.5	11.29	-76.4	4.93	-82.4	-2.31	-119.8	-4.63	-149.7	-3.46	-179.9	-11.72	81.0
15FEB89.DD	11.57	-60.9	17.55	-75.6	7.32	-99.1	-5.03	-179.9	-11.25	-221.9	-14.50	-254.1	-21.79	39.7
15FEB89.DE	18.22	-135.8	13.86	-99.5	5.58	-129.6	-5.89	-176.5	-12.99	-216.7	-14.25	-253.8	-21.25	23.0
15FEB89.DF	7.66	-45.7	7.95	-79.2	5.03	-91.9	-1.99	-113.2	-2.45	-143.6	-6.12	-182.1	-8.85	64.9
15FEB89.DG	10.49	-72.7	8.91	-81.5	5.20	-94.1	-1.33	-117.3	-3.39	-144.4	-4.33	-187.0	-7.90	62.0

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (SPEED)

RUN	0.10		0.30		0.50		0.70	
15FEB89.DF	10.82	-162.3	-.36	-150.2	4.62	-183.3	-4.23	-145.0
15FEB89.DG	13.00	-97.4	6.41	-158.4	-2.19	-156.5	-11.71	-149.3

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (PITCH)

RUN	0.20		0.50		0.90		1.40		2.40		4.20		9.00	
15FEB89.DH	20.18	-134.8	12.03	-123.6	6.91	-107.3	1.80	-127.0	-3.35	-142.5	-8.07	-159.5	-12.43	-220.0
15FEB89.DI	24.65	-162.0	15.06	-139.9	9.22	-127.0	4.05	-134.2	-2.23	-145.9	-7.17	-155.7	-12.64	-209.7
15FEB89.DJ	21.21	-107.0	13.72	-100.3	10.39	-123.0	3.90	-126.9	.16	-138.5	-4.20	-155.1	-7.73	-244.9
15FEB89.DK	27.30	-116.0	13.37	-128.6	8.48	-117.0	4.32	-133.7	-3.13	-147.9	-5.34	-159.7	-10.79	-241.5
15FEB89.DL	21.51	-186.2	15.96	-116.3	7.12	-129.9	2.74	-136.0	-4.02	-153.4	-4.82	-184.8	-8.12	27.5
15FEB89.DM	28.52	-141.2	11.82	-122.9	5.76	-122.4	2.01	-134.2	-5.57	-148.2	-5.19	-179.9	-6.61	46.2
15FEB89.DN	22.87	-91.4	14.36	-105.9	9.95	-124.6	5.09	-137.6	-.81	-149.4	-7.46	-155.4	-10.45	-204.6
15FEB89.DO	25.58	-117.8	14.51	-114.4	9.32	-117.5	4.84	-136.2	-3.06	-142.8	-8.84	-154.6	-11.08	-214.0
15FEB89.DP	14.54	-99.3	3.47	-101.4	-1.23	-110.3	-3.74	-118.0	-6.36	-128.6	-9.72	-137.0	-11.52	-4.5
15FEB89.DQ	11.73	-113.8	2.91	-89.2	.79	-106.8	-2.49	-118.4	-6.81	-114.0	-10.13	-186.8	-18.19	-6.0
15FEB89.DY	25.52	-115.7	10.13	-109.7	2.68	-125.6	-1.93	-126.7	-6.22	-133.0	-13.12	-152.5	-12.45	-198.0
15FEB89.DZ	14.20	-106.0	11.26	-115.3	6.28	-121.1	1.02	-126.6	-3.22	-144.1	-8.68	-142.7	-10.42	-202.8
15FEB89.EA	20.79	-139.1	12.05	-108.3	5.84	-116.4	1.81	-128.8	-5.05	-126.7	-8.92	-157.0	-10.47	-196.9
15FEB89.EB	17.79	-107.2	12.31	-113.7	5.25	-115.6	.74	-120.9	-5.18	-116.5	-10.14	-140.4	-9.14	-197.4
15FEB89.EC	17.66	-116.1	11.89	-111.2	8.10	-121.2	2.17	-125.8	-4.28	-130.5	-7.74	-148.5	-8.61	-201.6
15FEB89.ED	21.21	-167.3	12.45	-99.7	5.12	-118.6	1.95	-120.7	-2.96	-131.1	-9.02	-142.2	-8.10	-195.6
15FEB89.EE	18.20	-114.5	15.51	-124.0	8.03	-123.4	3.17	-116.4	-.31	-136.1	-6.20	-146.6	-7.20	-203.4
15FEB89.EF	17.79	-112.7	7.46	-93.9	4.21	-98.4	1.06	-93.3	-.09	-117.1	-4.54	-144.1	-6.02	-233.7
15FEB89.EG	20.20	-125.8	11.12	-95.4	4.72	-91.5	2.57	-99.4	.22	-101.0	-4.28	-143.5	-4.88	-241.5
15FEB89.EH	16.00	-126.3	7.10	-102.6	2.49	-108.6	-.61	-121.7	-4.19	-147.3	-5.48	-166.7	-5.35	42.9
15FEB89.EI	18.89	-110.3	9.13	-100.8	3.54	-109.6	.91	-113.7	-4.20	-148.9	-5.30	-169.5	-4.90	41.3
15FEB89.EJ	16.11	-116.6	9.46	-97.2	3.58	-110.5	.38	-120.0	-2.53	-141.9	-5.01	-161.3	-2.10	33.0
15FEB89.EK	19.04	-125.3	14.32	-124.5	8.23	-119.2	4.50	-125.5	-1.04	-133.0	-6.25	-148.5	-7.84	-192.5
15FEB89.EL	25.31	-116.9	15.03	-114.0	9.17	-119.2	4.68	-129.9	-.28	-131.1	-6.81	-154.4	-7.08	-196.3

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (ROLL)

RUN	0.30		0.40		0.70		1.80		3.00		4.00		7.00	
15FEB89.DR	23.91	-104.1	16.13	-81.7	12.97	-124.8	.67	-139.4	-4.20	-158.0	-6.85	-171.0	-9.27	-193.5
15FEB89.DS	24.82	-93.3	14.87	-117.3	12.07	-110.5	2.61	-141.4	-3.54	-147.8	-5.85	-171.8	-9.55	-203.3
15FEB89.DT	12.97	-74.1	14.20	-105.6	12.57	-110.1	.37	-148.9	-5.24	-161.4	-5.07	-185.3	-11.57	-253.1
15FEB89.DU	16.56	-46.1	16.78	-98.1	11.20	-109.3	.96	-145.6	-4.15	-175	-4.68	-187.4	-9.96	-240.5
15FEB89.DV	5.18	-87.5	12.33	17.7	7.46	-134.5	-2.28	-172.0	-10.11	-186.2	-10.52	-232.3	-18.30	6.4
15FEB89.DW	11.00	-99.5	9.81	-111.1	8.09	-106.5	.39	-136.5	-11.76	-191.5	-9.69	-248.1	-16.75	34.3
15FEB89.DY	.47	-75.9	25.25	-90.3	8.67	-106.8	1.47	-126.9	-4.23	-131.2	-5.40	-158.2	-7.50	-212.0
15FEB89.DZ	11.89	-36.4	17.55	-97.6	9.68	-89.3	2.40	-131.5	-1.96	-147.5	-4.47	-162.4	-5.34	-220.6
15FEB89.EA	14.80	-108.5	10.78	-99.9	12.92	-104.5	2.98	-131.8	-3.05	-144.0	-3.17	-136.8	-7.61	-213.3
15FEB89.EB	11.63	-92.5	11.21	-131.5	6.40	-97.9	.30	-135.6	-1.87	-148.5	-5.42	-168.6	-9.34	72.6
15FEB89.EC	19.54	-35.7	11.90	-95.7	6.33	-118.3	.07	-130.5	-7.37	-158.9	-4.37	-198.8	-9.13	89.2
15FEB89.ED	12.00	-90.4	10.67	-89.0	5.82	-92.3	.83	-137.8	-2.82	-157.9	-5.74	-185.2	-11.50	72.3
15FEB89.EE	15.03	-69.7	11.12	-71.8	11.03	-103.3	.07	-124.7	-1.87	-167.7	-5.00	-196.2	-9.90	75.3
15FEB89.EF	20.85	-116.4	15.18	-82.3	9.43	-111.8	-1.08	-138.1	-3.81	-171.7	-8.25	-189.3	-10.23	67.7
15FEB89.EG	10.19	-66.2	11.38	-72.7	10.46	-98.1	-.79	-138.6	-4.30	-153.4	-4.69	-195.4	-7.40	73.3
15FEB89.EH	9.32	-38.9	6.74	-86.6	8.33	-84.3	-.47	-134.1	-6.31	-170.5	-5.18	-180.9	-10.02	57.0
15FEB89.EI	12.03	-108.6	14.48	-118.0	10.60	-110.6	1.69	-136.7	-2.51	-160.0	-5.41	-178.1	-10.34	79.7
15FEB89.EJ	20.31	-150.7	12.93	-120.0	3.47	-103.4	-.35	-142.5	-3.64	-153.7	-3.82	-179.4	-10.35	76.5
15FEB89.EK	12.08	-117.4	20.62	-109.8	6.78	-103.0	-.79	-134.4	-4.55	-138.6	-7.49	-148.4	-6.56	-211.2
15FEB89.EL	14.39	-64.9	20.82	-111.0	9.84	-106.9	1.00	-134.2	-4.51	-146.5	-7.03	-145.4	-6.16	-203.5

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (SPEED)

RUN	0.10		0.30		0.50		0.70	
15FEB89.DX	16.64	-193.5	10.50	-83.5	.26	-133.2	1.24	-143.2

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (PITCH)

RUN	0.20		0.50		0.90		1.40		2.40		4.20		9.00	
16FEB89.AS	31.25	-110.7	18.81	-112.5	11.02	-126.2	4.99	-128.1	.50	-139.3	-4.29	-150.2	-7.64	-185.3
16FEB89.AT	23.87	-104.4	18.20	-105.9	10.41	-120.0	6.04	-131.0	.12	-131.7	-5.12	-153.4	-7.99	-189.4
16FEB89.AU	18.31	-85.6	12.90	-105.7	8.52	-108.6	4.38	-116.5	.16	-122.4	-3.29	-149.0	-6.56	-232.7
16FEB89.AV	19.61	-114.5	12.99	-111.1	9.35	-102.9	4.64	-121.5	.38	-128.5	-3.75	-151.2	-6.21	-227.1
16FEB89.AW	19.98	-122.9	11.81	-101.7	6.67	-126.6	1.74	-124.4	-4.65	-139.0	-4.82	-168.9	-7.55	40.8
16FEB89.AX	19.08	-105.6	11.35	-99.5	5.71	-117.6	2.23	-125.4	-2.24	-146.7	-4.92	-163.3	-4.31	38.2
16FEB89.AY	17.80	-124.2	12.01	-105.9	6.27	-115.4	2.05	-126.6	-2.86	-143.0	-5.22	-166.4	-2.69	66.8
16FEB89.BF	20.95	-139.6	15.37	-106.2	6.46	-124.9	1.13	-133.1	-4.95	-126.6	-7.97	-138.9	-7.64	-178.0
16FEB89.BG	19.39	-112.9	14.32	-110.0	7.89	-125.0	2.93	-130.7	-4.43	-125.2	-7.76	-147.6	-6.83	-178.5
16FEB89.BH	20.86	-35.6	15.77	-125.5	7.37	-127.8	2.94	-120.6	-3.38	-137.9	-6.22	-136.5	-6.63	-176.5
16FEB89.BI	21.14	-96.5	12.62	-114.3	5.57	-106.8	2.53	-109.1	-3.12	-118.8	-3.99	-133.7	-5.01	-217.9
16FEB89.BJ	19.99	-78.8	10.32	-103.6	4.79	-102.7	1.25	-105.5	-.14	-111.6	-3.28	-136.7	-4.45	-214.9
16FEB89.BK	18.03	-88.2	11.25	-87.1	4.78	-106.5	1.69	-98.8	-1.35	-117.4	-2.81	-138.2	-5.59	-214.4
16FEB89.BL	20.89	-102.9	10.59	-107.7	5.47	-111.0	1.83	-109.6	-2.71	-119.2	-4.23	-140.1	-4.25	-211.7
16FEB89.BM	17.38	-68.8	10.40	-95.1	4.51	-105.9	1.87	-103.0	-1.86	-116.0	-4.97	-140.3	-5.40	-209.0
16FEB89.BN	20.78	-127.1	12.93	-106.2	4.93	-108.5	2.61	-109.3	-3.82	-112.5	-5.32	-139.4	-5.96	-218.7
16FEB89.BO	19.73	-119.0	10.27	-111.9	6.48	-114.4	1.42	-116.0	-2.84	-132.3	-4.18	-150.8	.57	48.3
16FEB89.BP	18.24	-135.0	9.52	-118.0	3.57	-108.2	.32	-117.2	-1.56	-127.5	-3.93	-149.2	-.22	63.8
16FEB89.BQ	23.28	-130.1	9.44	-110.5	2.92	-117.3	-1.76	-123.6	-7.94	-120.3	-9.34	-124.2	-7.04	-176.4
16FEB89.BR	15.07	-134.5	10.75	-112.8	4.35	-122.7	-.75	-113.2	-4.82	-129.6	-9.34	-132.9	-7.35	-182.2
16FEB89.BS	19.72	-57.6	14.01	-119.3	7.97	-125.1	2.47	-128.4	-3.12	-132.2	-7.25	-140.3	-7.78	-185.1
16FEB89.BT	23.87	-169.5	12.44	-109.2	8.50	-114.6	3.65	-128.2	-2.21	-124.6	-6.29	-138.6	-7.02	-184.1
16FEB89.BU	25.90	-158.5	14.36	-120.2	8.21	-118.2	3.74	-128.0	-3.16	-126.3	-7.40	-145.9	-7.60	-184.4
16FEB89.BV	21.62	-138.9	9.55	-107.2	3.87	-104.0	-.22	-104.1	-2.35	-127.8	-3.48	-145.3	.44	57.8
16FEB89.BW	19.13	-62.5	6.22	-115.9	1.62	-99.6	-.92	-102.8	-3.87	-130.1	-3.84	-139.3	.12	55.6
16FEB89.BX	19.01	-110.9	11.23	-114.3	5.80	-99.0	2.69	-110.7	-1.64	-125.9	-4.22	-140.6	-4.57	-213.3
16FEB89.BY	19.51	-109.0	12.04	-112.4	6.79	-102.9	3.94	-105.6	-1.47	-126.9	-5.09	-138.3	-4.85	-211.6
16FEB89.BZ	23.09	-121.4	11.16	-103.0	6.64	-94.4	3.56	-99.9	-.13	-128.7	-3.88	-139.4	-4.67	-212.7
16FEB89.CB	18.30	48.6	9.53	-91.8	4.04	-104.8	1.44	-100.8	-5.12	-96.0	-6.36	-139.6	-5.80	-229.9
16FEB89.CC	18.93	-135.5	13.02	-74.3	4.71	-113.7	2.78	-120.1	-2.56	-126.3	-5.20	-142.0	-5.33	-220.6
16FEB89.CD	18.26	-123.5	9.15	-87.6	6.12	-115.6	2.85	-116.1	-2.01	-123.0	-5.22	-135.6	-5.59	-226.7

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (ROLL)

RUN	0.30		0.40		0.70		1.80		3.00		4.00		7.00	
16FEB89.AZ	15.46	-35.2	17.71	-111.2	8.41	-99.6	-1.13	-126.3	-6.77	-147.9	-5.46	-163.6	-6.98	-229.5
16FEB89.BA	20.19	-95.9	9.89	-84.0	6.76	-109.1	-.98	-124.9	-5.78	-148.5	-6.23	-161.4	-6.73	-224.8
16FEB89.BB	18.10	-89.8	14.88	-106.6	10.34	-101.3	-.39	-119.6	-5.14	-130.2	-7.55	-153.6	-8.55	-173.6
16FEB89.BC	14.03	-73.0	12.89	-78.7	10.35	-112.1	-.05	-124.1	-7.65	-143.6	-8.12	-148.0	-9.08	-183.1
16FEB89.BD	10.82	-77.9	15.09	15.6	9.47	-135.3	-2.14	-143.9	-4.20	-181.1	-7.59	-215.1	-12.97	43.3
16FEB89.BE	21.32	-20.9	7.20	-70.9	5.88	-126.6	-1.87	-137.7	-4.10	-184.4	-7.96	-232.0	-13.66	43.3
16FEB89.BF	16.14	-91.2	16.34	-105.7	6.72	-112.1	-1.95	-122.2	-7.51	-123.7	-9.68	-146.2	-8.13	-178.3
16FEB89.BG	15.76	-95.2	17.80	-82.2	10.00	-107.4	-2.55	-117.9	-5.91	-150.0	-9.19	-159.7	-8.32	-181.6
16FEB89.BH	11.44	-72.4	14.94	-134.2	6.47	-111.9	-3.59	-127.2	-6.33	-138.9	-10.05	-145.6	-8.41	-194.2
16FEB89.BI	14.78	-100.4	15.38	-117.5	7.97	-91.8	-1.27	-126.0	-4.57	-139.7	-8.64	-147.4	-7.95	-182.8
16FEB89.BJ	20.18	-79.9	14.99	-109.4	6.39	-106.4	-2.66	-130.4	-4.36	-148.2	-6.86	-151.3	-8.82	-181.2
16FEB89.BK	20.56	-131.7	13.80	-122.9	9.71	-123.0	-.06	-129.4	-7.03	-127.0	-6.13	-136.4	-6.23	-184.6
16FEB89.BL	9.54	-108.8	14.22	-85.3	8.14	-118.9	-1.30	-134.6	-4.51	-162.8	-4.83	-170.8	-7.29	-265.7
16FEB89.BM	23.41	-98.8	9.64	-88.4	8.44	-112.0	-.65	-128.4	-4.93	-153.0	-5.80	-170.3	-6.74	-266.1
16FEB89.BN	14.64	-44.6	11.06	-99.6	6.88	-121.6	-3.13	-129.1	-7.27	-153.7	-7.00	-171.7	-7.37	-246.5
16FEB89.BO	17.37	-84.2	10.73	-83.5	7.40	-120.2	-3.83	-133.5	-6.44	-149.5	-4.82	-164.4	-5.06	-239.5
16FEB89.BP	17.45	-90.1	13.78	-107.5	8.09	-93.1	-.89	-129.8	-3.82	-146.1	-5.34	-169.3	-4.79	-258.6
16FEB89.BQ	11.81	27.8	9.47	-68.4	15.02	-99.2	-1.91	-155.1	-5.43	-179.0	-6.71	-230.8	-15.29	20.6
16FEB89.BR	1.40	-14.2	8.79	-105.0	6.18	-105.6	.00	-149.1	-3.79	-178.8	-7.78	-206.2	-14.77	22.1
16FEB89.BS	14.07	-88.9	14.17	-97.6	7.32	-122.2	-2.19	-128.9	-10.45	-106.9	-10.35	-162.7	-6.02	-178.8
16FEB89.BT	19.83	-129.4	12.66	-87.3	8.46	-124.0	-.19	-130.8	-8.84	-154.0	-8.67	-97.7	-6.42	-192.5
16FEB89.BU	16.23	-148.4	13.79	-110.4	8.34	-112.2	-2.15	-125.4	-8.94	-130.1	-7.21	-148.1	-8.22	-190.6
16FEB89.BV	12.96	-123.7	9.78	-132.0	6.14	-134.1	-2.57	-139.8	-7.74	-231.4	-7.12	-235.0	-14.78	13.2
16FEB89.BW	10.64	-80.6	3.09	-42.6	5.90	-134.4	-1.48	-142.5	-2.50	-207.6	-7.59	-241.7	-20.88	22.1
16FEB89.BX	19.89	-70.6	14.55	-80.9	6.57	-119.2	-1.01	-131.3	-7.41	-155.3	-4.14	-164.2	-5.36	-260.6
16FEB89.BY	34.39	-260.0	18.63	-106.6	8.27	-124.3	-2.69	-133.9	-4.13	-141.9	-5.54	-170.8	-5.62	-243.2
16FEB89.BZ	9.88	-92.9	9.48	-126.5	8.26	-119.0	-3.11	-125.0	-5.70	-119.7	-6.77	-156.7	-3.97	-252.1
16FEB89.CB	12.09	-104.0	12.55	-142.9	4.98	-115.8	-.30	-129.9	-10.74	-129.7	-6.12	-184.7	-11.72	64.8
16FEB89.CC	12.27	-131.6	10.76	-104.5	4.17	-131.1	-3.69	-130.5	-6.21	-151.1	-6.66	-178.6	-6.89	-256.5
16FEB89.CD	12.81	-118.3	16.91	-141.4	9.94	-120.0	-2.97	-132.0	-6.76	-176.5	-12.05	-203.8	-9.32	48.4

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (SPEED)

RUN	0.10		0.30		0.50		0.70	
16FEB89.CA	26.31	-213.0	11.87	-128.4	5.95	-122.4	2.26	-132.7
16FEB89.CB	12.88	-175.0	5.67	-133.3	-2.22	-132.0	-2.23	-168.4
16FEB89.CC	12.35	-164.6	.25	-146.3	-.22	-74.3	-6.70	-175.8
16FEB89.CD	11.45	-184.7	3.46	-148.3	-.49	-146.2	-3.49	-148.3

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (PITCH)

RUN	0.20		0.50		0.90		1.40		2.40		4.20		9.00	
17FEB89.AB	38.54	-34.1	18.72	-109.1	11.04	-117.3	6.85	-133.3	.17	-134.1	-3.67	-150.9	-4.97	-197.7
17FEB89.AC	35.13	-114.9	19.80	-111.9	11.62	-123.0	6.83	-132.0	.93	-132.7	-2.87	-148.8	-5.65	-194.0
17FEB89.AD	24.92	-104.9	15.67	-104.1	10.92	-109.3	6.73	-119.2	3.79	-118.9	-.77	-143.9	-3.42	-227.3
17FEB89.AE	23.66	-113.8	13.58	-102.3	10.64	-111.5	6.04	-118.5	1.73	-110.7	-1.72	-144.9	-2.07	-219.5
17FEB89.AF	21.01	-106.7	10.76	-99.1	6.45	-109.7	1.77	-127.7	-2.34	-127.3	-2.24	-159.5	-.97	61.0
17FEB89.AG	18.59	-105.6	12.54	-104.3	8.26	-119.7	2.65	-128.7	-1.54	-131.4	-2.73	-158.1	.84	56.9
17FEB89.AH	25.05	-87.6	14.39	-93.7	9.77	-113.8	4.84	-121.0	-.99	-124.4	-3.07	-140.8	-2.72	-228.4
17FEB89.AI	21.65	-99.0	15.33	-91.6	10.63	-112.6	6.65	-121.0	1.48	-136.0	-1.98	-140.0	-2.35	-227.2
17FEB89.AJ	11.46	-102.5	4.84	-96.3	.49	-112.4	-.69	-116.8	-5.65	-134.9	-6.33	-158.2	-9.73	-26.2
17FEB89.AK	17.77	-97.8	5.73	-99.2	2.70	-112.5	-2.43	-113.6	-6.78	-131.4	-7.03	-159.7	-10.36	-9.7
17FEB89.AL	15.66	-86.5	8.08	-103.7	1.92	-104.2	-.64	-105.6	-4.37	-127.9	-7.89	-174.8	-9.90	-21.8
17FEB89.AU	24.52	-142.3	14.38	-129.7	6.25	-131.3	.42	-119.9	-2.56	-135.6	-7.79	-147.2	-8.71	-196.9
17FEB89.AV	25.43	-109.1	14.52	-121.6	6.24	-122.7	2.15	-124.9	-4.11	-128.7	-6.48	-143.5	-7.01	-201.2
17FEB89.AW	19.00	-91.4	16.61	-133.0	7.25	-123.8	3.24	-123.8	-1.17	-123.9	-6.29	-144.4	-6.70	-197.0
17FEB89.AX	16.06	-108.4	11.06	-107.8	4.55	-109.8	1.87	-109.4	-4.47	-122.7	-3.11	-154.4	-.33	35.5
17FEB89.AY	12.15	-98.8	9.97	-112.7	2.77	-114.9	-.22	-117.4	-4.33	-127.3	-2.78	-146.2	.83	55.2
17FEB89.AZ	15.12	-111.3	7.45	-106.0	.58	-108.7	-2.12	-120.2	-6.47	-127.9	-4.73	-152.5	-2.75	20.1
17FEB89.BA	23.93	-154.9	12.91	-103.4	4.86	-107.0	1.64	-108.2	-2.59	-113.2	-3.47	-132.8	-2.47	-232.6
17FEB89.BB	30.25	-4.7	10.08	-86.0	4.75	-100.5	1.25	-101.9	-4.08	-104.8	-3.81	-131.6	-2.25	-243.9
17FEB89.BC	18.54	-114.5	8.24	-106.9	1.34	-98.1	-2.01	-102.0	-4.90	-97.0	-4.12	-122.8	-3.25	-235.1
17FEB89.BD	9.00	-100.3	7.42	-103.4	3.57	-93.3	-1.92	-83.1	-.42	-92.4	-3.59	-128.6	-3.17	-229.3
17FEB89.BE	28.05	-89.2	6.66	-97.1	2.48	-110.8	-1.67	-110.0	-5.10	-103.4	-3.48	-129.7	-3.31	-233.3
17FEB89.BF	23.52	-121.2	7.77	-94.5	3.90	-100.9	1.68	-102.8	-2.48	-102.7	-2.91	-125.4	-2.03	-226.8
17FEB89.BG	14.64	-79.6	1.72	-103.2	-3.82	-100.0	-6.78	-106.4	-7.79	-113.8	-7.82	-139.0	-7.38	-3.4
17FEB89.BH	11.91	-101.6	3.83	-95.5	-2.36	-98.1	-4.30	-104.1	-8.80	-123.6	-8.00	-147.1	-4.20	2.4
17FEB89.BI	9.66	-65.8	1.57	-86.7	-3.43	-102.9	-6.58	-96.3	-8.71	-139.6	-7.47	-140.9	-8.49	-15.2
17FEB89.BJ	7.13	-102.0	1.53	-90.4	-3.98	-100.6	-3.00	-106.2	-7.97	-118.8	-8.73	-141.0	-4.68	-12.0
17FEB89.BK	8.68	-81.8	2.65	-82.7	-2.45	-102.6	-4.17	-100.5	-8.35	-115.0	-7.02	-151.2	-7.17	-11.9
17FEB89.BL	11.76	-105.7	8.07	-95.2	2.85	-101.8	-2.26	-94.6	-6.53	-123.6	-4.55	-156.3	.27	32.1
17FEB89.BM	13.02	-50.5	7.11	-90.9	3.40	-112.6	.85	-115.3	-3.93	-130.8	-4.96	-148.2	2.05	32.3
17FEB89.BN	10.55	-76.0	8.93	-101.8	2.39	-96.3	-.50	-107.0	-4.43	-134.2	-4.86	-152.8	.24	20.7

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (ROLL)

RUN	0.30		0.40		0.70		1.80		3.00		4.00		7.00	
17FEB89.AM	16.82	-96.5	20.05	-105.3	12.86	-109.2	2.86	-131.0	-1.73	-152.3	-5.13	-171.1	-8.25	-185.0
17FEB89.AN	19.52	-57.9	15.17	-52.3	13.35	-109.4	2.70	-136.5	-3.85	-150.2	-6.11	-169.1	-8.83	-188.3
17FEB89.AO	18.20	-47.6	16.46	-102.9	12.41	-93.1	1.88	-138.4	-1.41	-158.4	-4.66	-181.4	-9.73	-250.3
17FEB89.AP	18.50	-88.4	16.01	-79.3	8.74	-97.9	.45	-131.5	-3.11	-160.5	-4.79	-183.7	-9.70	-253.7
17FEB89.AQ	9.04	-90.0	5.58	-79.6	5.74	-99.3	-2.01	-164.3	-11.20	-244.4	-12.65	-229.6	-17.29	42.6
17FEB89.AR	5.93	-35.5	5.86	-93.2	9.39	-114.7	.57	-152.3	-4.27	-200.8	-13.61	-230.5	-18.42	65.9
17FEB89.AS	6.04	-60.2	7.39	-62.7	6.59	-71.9	1.42	-156.3	-4.56	-202.1	-8.86	-249.5	-14.24	21.9
17FEB89.AT	6.96	-15.7	9.35	.9	5.21	-90.0	.01	-140.2	-6.12	-206.9	-10.94	-247.7	-16.21	31.3
17FEB89.AU	18.91	-72.3	12.87	-75.1	6.85	-102.2	-2.36	-112.4	-3.48	-134.3	-5.99	-155.3	-6.59	-192.4
17FEB89.AV	19.07	-105.8	10.61	-19.5	11.56	-96.9	3.12	-121.8	.62	-139.3	-2.11	-150.6	-5.35	-192.1
17FEB89.AW	17.08	-64.4	11.11	-67.8	10.77	-110.7	3.52	-134.7	-1.70	-140.7	-4.47	-152.0	-5.19	-186.3
17FEB89.AX	10.38	-5.5	16.00	-69.7	10.99	-111.5	-1.55	-134.1	-3.10	-154.6	-5.96	-176.1	-8.36	83.1
17FEB89.AY	25.03	-49.6	15.59	-66.7	7.66	-91.7	.04	-134.7	-5.75	-154.1	-4.12	-189.0	-6.65	-255.6
17FEB89.AZ	16.14	-115.2	11.09	-59.3	8.71	-110.9	-.76	-131.4	-4.07	-161.9	-4.95	-183.4	-9.33	-265.4
17FEB89.BA	12.28	-49.6	11.01	-54.6	12.40	-56.3	1.54	-131.0	-2.01	-158.9	-6.42	-180.7	-9.39	-264.8
17FEB89.BB	8.70	-66.3	11.27	-71.2	6.92	-73.1	2.48	-131.3	-1.78	-143.0	-4.03	-193.3	-7.23	-264.5
17FEB89.BC	9.89	-55.1	5.98	-46.6	4.70	-91.4	-1.28	-159.6	-6.35	-189.9	-7.67	-266.2	-19.37	58.7
17FEB89.BD	7.66	-12.4	5.68	-77.8	5.26	-95.2	-1.90	-153.3	-3.76	-193.8	-11.68	-256.8	-18.20	3.8
17FEB89.BE	5.11	-36.9	13.20	-78.1	5.57	-99.9	-.28	-151.1	-17.23	-120.2	-7.89	-237.1	-11.82	-8.4
17FEB89.BF	8.25	-114.3	6.92	-3.8	1.17	-75.7	1.23	-151.1	-4.86	-223.4	-9.76	84.1	-16.62	4.0
17FEB89.BG	12.65	-96.5	11.03	-70.4	8.76	-122.9	-2.56	-126.4	-5.57	-176.2	-5.47	-177.3	-11.53	70.3
17FEB89.BH	13.38	-59.1	8.84	-91.4	7.18	-105.1	-2.11	-115.0	-4.51	-157.0	-5.65	-185.1	-9.43	71.3
17FEB89.BI	14.63	-102.0	7.32	-79.2	3.47	-86.0	-4.38	-126.1	-4.99	-165.6	-6.32	-197.0	-10.39	65.0
17FEB89.BJ	9.44	-83.5	9.86	-66.6	3.96	-97.8	-4.73	-128.6	-5.44	-155.8	-5.06	-176.2	-12.14	70.8
17FEB89.BK	12.78	-57.3	10.43	-80.0	5.82	-101.7	-3.19	-136.8	-5.32	-154.5	-8.36	-180.6	-11.56	59.4
17FEB89.BL	7.09	-87.8	15.58	-100.4	4.30	-97.0	-1.40	-159.2	-14.00	-195.0	-8.13	-240.3	-13.49	2.4
17FEB89.BM	11.93	-90.8	7.59	-64.0	10.28	-87.2	-.12	-158.9	-2.97	-222.6	-9.71	-264.4	-21.46	33.0
17FEB89.BN	11.74	-35.5	4.86	-75.6	6.33	-82.3	-2.56	-147.8	-8.11	-212.9	-10.93	-247.3	-19.05	3.6

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (PITCH)

RUN	0.20		0.50		0.90		1.40		2.40		4.20		9.00	
21FEB89.AB	23.38	-56.3	16.70	-98.1	9.94	-105.8	5.55	-113.2	-.86	-134.6	-5.23	-143.4	-6.16	-199.4
21FEB89.AC	21.36	-122.5	14.90	-118.5	8.99	-104.4	4.83	-110.0	-.16	-126.6	-4.71	-143.9	-6.75	-195.3
21FEB89.AD	19.10	-100.4	11.21	-96.9	7.95	-94.3	5.18	-105.8	.29	-119.4	-.69	-143.5	-5.51	-234.0
21FEB89.AE	20.01	-72.0	12.34	-79.9	7.88	-95.2	4.81	-100.9	-.66	-108.7	-2.73	-145.1	-4.72	-229.4
21FEB89.AF	15.84	-85.5	10.68	-94.9	5.80	-103.4	.99	-109.5	-2.32	-139.6	-3.12	-163.3	.42	41.9
21FEB89.AG	17.83	-70.7	11.77	-99.6	6.38	-100.4	4.10	-118.2	-2.72	-124.2	-4.77	-155.2	-2.06	47.6
21FEB89.AH	14.06	-97.2	9.17	-93.1	5.24	-95.3	3.36	-122.4	-2.30	-139.9	-4.68	-162.9	-1.42	16.5
21FEB89.AI	13.49	-79.3	7.06	-85.9	4.61	-92.9	2.01	-110.2	-2.51	-126.2	-6.30	-136.1	-4.91	-267.5
21FEB89.AJ	16.19	-99.9	10.46	-89.6	6.25	-87.6	4.09	-115.8	-3.40	-133.6	-7.77	-145.1	-5.40	-247.7
21FEB89.AK	16.19	-96.2	10.36	-103.9	6.47	-108.6	3.05	-129.0	-4.84	-147.9	-4.79	-162.6	-2.10	26.6
21FEB89.AL	17.00	-96.2	13.76	-94.5	8.52	-108.0	3.37	-131.7	-2.74	-150.1	-5.81	-158.7	-1.47	25.6
21FEB89.AM	12.94	-107.5	6.62	-92.5	3.91	-103.0	.34	-120.0	-4.61	-146.4	-11.24	-150.5	-4.05	-35.9
21FEB89.AN	14.96	-90.3	7.16	-104.3	3.79	-105.5	-1.36	-114.0	-3.11	-131.7	-6.65	-171.7	-8.31	-37.6
21FEB89.AO	14.19	-71.9	8.19	-106.0	3.72	-109.3	1.84	-116.7	-3.06	-139.3	-6.31	-167.7	-6.14	-13.7
21FEB89.AV	20.81	-103.6	11.64	-102.9	6.79	-107.3	3.77	-126.3	-3.29	-142.5	-8.13	-144.2	-8.14	-197.1
21FEB89.AW	21.42	-129.7	11.58	-110.7	7.63	-116.9	3.59	-126.3	-2.68	-143.6	-8.48	-146.0	-8.04	-198.5
21FEB89.AX	20.63	-79.5	10.25	-94.8	5.39	-94.8	5.47	-101.6	-2.07	-143.4	-4.76	-152.5	-3.16	-232.6
21FEB89.AY	16.03	-104.3	9.84	-88.9	5.93	-86.8	8.76	-106.4	-1.19	-133.1	-6.06	-150.2	-3.34	-223.7
21FEB89.AZ	14.83	-97.5	10.99	-90.7	8.33	-98.0	5.82	-99.8	1.75	-133.2	-4.33	-148.0	-5.91	-220.4
21FEB89.BA	19.60	-100.7	9.10	-89.9	6.32	-84.8	5.39	-100.5	-1.56	-127.8	-4.23	-147.0	-1.96	-231.3
21FEB89.BB	14.49	-112.0	9.53	-88.6	5.15	-94.1	3.67	-117.2	-2.77	-146.7	-5.30	-167.9	.80	43.5
21FEB89.BC	20.33	-79.4	7.00	-94.5	3.96	-100.3	2.45	-126.5	-4.44	-130.3	-5.17	-157.3	1.56	42.7

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (ROLL)

RUN	0.30		0.40		0.70		1.80		3.00		4.00		7.00	
21FEB89.AP	16.17	-79.6	12.59	-86.0	11.07	-109.8	.60	-123.6	-4.16	-144.8	-6.27	-147.9	-9.01	-195.7
21FEB89.AQ	19.77	-77.8	15.06	-81.7	11.09	-104.4	3.21	-112.6	-.91	-141.7	-4.26	-145.7	-7.07	-201.0
21FEB89.AR	16.95	-58.3	13.94	-83.1	8.54	-93.9	-.29	-130.1	-4.84	-153.4	-7.00	-184.8	-10.88	-236.8
21FEB89.AS	13.41	-101.7	11.50	-96.6	7.10	-102.0	-.84	-127.1	-6.20	-159.3	-6.73	-176.3	-11.27	-234.7
21FEB89.AT	8.13	-66.9	9.87	-63.2	6.77	-116.8	-3.09	-151.8	-5.73	-194.1	-8.43	-238.1	-17.24	56.4
21FEB89.AU	12.58	-86.1	7.68	-83.8	4.61	-114.6	-3.89	-150.5	-6.99	-189.4	-10.07	-235.9	-18.23	58.3
21FEB89.AV	11.98	-90.6	9.74	-68.8	4.28	-86.1	-2.40	-124.6	-7.40	-148.5	-8.10	-155.0	-8.30	-208.8
21FEB89.AW	13.77	-64.2	12.98	-62.2	5.55	-96.3	-2.54	-122.1	-6.82	-143.5	-7.29	-150.9	-10.44	-233.0
21FEB89.AX	13.76	-62.5	12.17	-98.9	4.58	-103.7	-.66	-131.2	-4.30	-156.7	-6.76	-192.9	-8.70	89.6
21FEB89.AY	8.71	-61.5	8.71	-83.7	2.13	-90.1	-1.75	-129.3	-5.03	-169.3	-7.51	-180.6	-12.49	86.5
21FEB89.AZ	7.79	-91.8	17.69	-8.6	2.34	-117.0	-5.02	-169.6	-11.28	-222.9	-12.29	-246.5	-22.55	33.8
21FEB89.BA	18.86	-41.7	8.17	-96.2	5.20	-135.3	-4.76	-174.3	-12.35	-219.2	-16.73	-210.7	-21.22	25.3
21FEB89.BB	6.60	-40.5	8.90	-54.6	1.01	-96.9	-4.65	-121.9	-7.53	-162.6	-7.72	-177.9	-12.96	65.1
21FEB89.BC	3.18	-42.8	3.74	-84.8	1.70	-75.2	-4.30	-130.5	-5.53	-154.9	-7.80	-186.1	-12.21	62.7

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (PITCH)

RUN	0.20		0.50		0.90		1.40		2.40		4.20		9.00	
21FEB89.BE	23.46	-94.4	15.03	-106.8	12.38	-132.4	5.96	-140.8	.19	-151.9	-6.16	-168.1	-11.89	-230.5
21FEB89.BF	23.59	-78.7	11.47	-88.0	6.35	-121.7	1.33	-129.8	-4.52	-160.9	-5.71	-179.9	-9.75	28.0
21FEB89.BG	16.42	-120.5	10.67	-103.0	5.92	-113.1	2.01	-138.0	-4.31	-151.7	-5.08	-186.7	-6.09	13.1
21FEB89.BM	21.22	-110.5	10.37	-116.2	4.59	-114.4	-.43	-126.7	-6.04	-139.5	-11.03	-158.5	-11.48	-204.8
21FEB89.BN	21.03	-121.0	13.17	-114.0	7.67	-122.1	3.32	-127.1	-3.23	-134.2	-8.32	-152.8	-9.46	-204.4
21FEB89.BO	15.89	-151.3	8.73	-116.6	4.18	-112.6	-.18	-113.1	-2.88	-135.4	-5.31	-172.6	-5.65	30.0
21FEB89.BP	18.76	-101.6	7.90	-111.0	3.84	-107.9	1.49	-110.8	-4.21	-145.1	-5.22	-167.3	-2.34	22.3
21FEB89.BQ	19.08	-159.0	10.78	-104.4	5.34	-103.1	2.33	-108.2	-1.61	-124.7	-5.31	-143.7	-4.87	-253.4
21FEB89.BR	19.89	-131.2	10.52	-110.5	6.93	-109.0	5.03	-104.9	-2.80	-128.0	-4.82	-147.6	-4.27	-246.3
21FEB89.BS	10.37	-141.8	2.30	-92.2	.81	-89.7	-4.07	-69.7	-2.32	-98.9	-6.27	-137.4	-5.70	-260.7
21FEB89.BT	16.41	-91.6	7.77	-104.2	3.62	-94.6	-1.39	-81.1	-3.30	-129.5	-6.06	-133.1	-5.13	-266.0
21FEB89.BU	11.22	-105.2	7.90	-110.9	4.63	-111.5	1.69	-118.5	-1.57	-147.3	-5.04	-164.8	-3.72	24.3
21FEB89.BV	19.77	-124.8	8.63	-92.2	4.30	-115.3	1.71	-125.2	-3.54	-149.5	-6.14	-165.2	-3.57	20.5
21FEB89.BW	15.71	-102.6	11.34	-100.8	7.99	-120.1	3.22	-130.7	-2.49	-147.2	-8.12	-156.0	-10.45	-213.5
21FEB89.BX	25.28	-172.5	11.27	-124.2	6.44	-122.4	2.05	-140.1	-5.51	-137.6	-9.38	-159.0	-11.98	-218.2
21FEB89.BZ	13.65	-131.6	5.03	-96.7	.37	-108.2	-2.97	-103.2	-5.31	-124.6	-4.93	-164.5	-12.63	-19.6
21FEB89.CA	17.21	-130.1	1.54	-95.8	-1.56	-105.0	-4.05	-108.0	-5.85	-134.0	-5.65	-142.0	-8.80	-29.5
21FEB89.CB	7.70	-141.1	6.54	-112.6	1.73	-97.3	1.32	-86.0	-6.37	-130.3	-8.05	-136.2	-6.45	-256.1
21FEB89.CC	17.58	-198.9	2.31	-93.0	.05	-99.2	-2.92	-85.5	-2.47	-130.0	-6.87	-146.1	-5.83	-261.8
21FEB89.CE	12.72	-84.7	12.53	-110.4	3.56	-126.3	-.36	-135.6	-5.52	-146.7	-9.90	-156.5	-12.05	-211.7
21FEB89.CF	20.34	-83.8	10.12	-105.3	4.60	-115.2	.21	-134.8	-4.88	-142.6	-9.46	-151.5	-11.80	-230.4
21FEB89.CG	16.47	-96.5	11.35	-107.3	7.08	-107.1	3.00	-110.5	.12	-131.1	-5.79	-150.8	-5.48	-248.1
21FEB89.CH	17.96	-98.2	9.80	-104.0	6.44	-111.1	4.28	-116.0	-2.76	-133.1	-5.53	-150.0	-4.53	-256.8

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (ROLL)

RUN	0.30		0.40		0.70		1.80		3.00		4.00		7.00	
21FEB89.BH	16.75	-131.0	18.06	-122.2	12.44	-126.3	1.46	-145.2	-3.24	-170.4	-5.84	-191.4	-9.06	88.0
21FEB89.BI	14.38	-61.9	29.82	-212.6	15.49	-167.3	1.13	-145.5	-2.67	-166.4	-5.33	-193.2	-8.68	-265.1
21FEB89.BJ	11.92	-91.3	13.05	-85.1	12.99	-132.0	1.45	-134.8	-5.29	-166.3	-5.73	-196.4	-10.62	84.9
21FEB89.BK	26.28	-203.9	10.60	-50.0	8.27	-142.2	-2.21	-148.6	-11.60	-248.9	-8.13	-239.8	-17.85	30.8
21FEB89.BL	14.12	-142.8	10.72	-70.0	10.70	-152.5	-.11	-157.2	-5.81	-206.3	-10.08	35.6	-16.45	30.9
21FEB89.BM	10.76	-90.7	10.31	-70.4	5.74	-106.6	-.29	-126.9	-3.34	-144.3	-9.42	-171.2	-6.86	-207.5
21FEB89.BN	12.23	-97.4	16.40	-79.4	8.05	-108.2	-.62	-134.0	-7.20	-162.9	-16.03	-143.7	-7.51	-214.0
21FEB89.BO	8.67	-71.3	5.56	-70.6	6.18	-117.0	-4.96	-141.6	-3.80	-162.0	-3.11	-169.5	-7.95	78.9
21FEB89.BP	10.57	-55.3	12.94	-75.4	9.60	-125.6	-.67	-133.8	-7.85	-176.8	-4.64	-177.9	-12.07	32.3
21FEB89.BQ	15.72	-79.4	15.61	-76.7	9.97	-105.7	-.19	-137.0	-4.44	-155.2	-5.44	-187.6	-10.60	68.1
21FEB89.BR	12.22	-62.1	13.89	-73.9	8.33	-114.4	-.80	-140.6	-4.61	-168.3	-7.34	-200.0	-10.78	62.1
21FEB89.BS	8.06	-150.1	3.24	-8.8	10.34	-119.0	-2.33	-164.5	-12.93	-209.4	-5.69	-240.4	-16.25	-10.9
21FEB89.BT	18.51	82.7	4.99	-65.4	2.29	-91.9	-1.64	-164.5	-4.01	-213.8	-9.21	77.9	-23.74	17.3
21FEB89.BU	23.85	-77.1	27.08	-70.4	7.70	-112.8	-2.49	-132.8	-4.31	-150.0	-11.36	-166.7	-8.07	41.7
21FEB89.BV	12.95	-71.3	8.99	-61.3	3.81	-109.8	-.94	-134.0	-6.87	-161.4	-3.72	-195.8	-12.85	50.1
21FEB89.BW	19.98	-2.7	17.48	-54.6	6.75	-88.8	-1.48	-127.7	-5.14	-140.2	-8.72	-153.0	-6.08	-205.3
21FEB89.BX	15.78	-98.8	13.77	-78.5	6.40	-96.8	-1.16	-134.2	-6.05	-136.7	-6.04	-166.3	-7.05	-216.7
21FEB89.BZ	8.07	-48.7	16.94	-114.5	5.14	-102.2	-3.36	-141.7	-10.05	-154.7	-6.46	-216.5	-20.14	57.9
21FEB89.CA	10.19	-115.8	5.97	-110.4	6.22	-116.2	-3.56	-148.9	-4.15	-167.1	-6.60	-203.4	-15.38	26.3
21FEB89.CB	20.63	8.5	1.57	-106.8	1.00	-88.8	1.37	-120.8	-8.09	-194.6	-12.51	-229.5	-20.78	38.2
21FEB89.CC	15.86	-179.6	4.14	-68.3	4.76	-124.5	-.50	-156.8	-4.13	-223.2	-8.19	54.3	-20.75	12.8
21FEB89.CE	14.58	-20.2	14.50	-67.4	4.81	-99.8	-2.15	-135.2	-6.52	-130.2	-11.49	-137.1	-7.84	-251.2
21FEB89.CF	12.35	-64.5	8.97	-74.0	12.95	-88.4	-4.14	-133.2	-9.25	-147.9	-17.75	-183.7	-8.34	-231.0
21FEB89.CG	15.06	-13.4	8.20	-78.7	7.09	-76.6	-3.39	-136.9	-6.95	-159.2	-6.00	-189.7	-13.53	56.6
21FEB89.CH	7.64	-67.4	11.43	-54.8	5.58	-74.4	-1.62	-142.4	-2.83	-163.8	-5.07	-205.2	-12.24	37.3

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (SPEED)

RUN	0.10		0.30		0.50		0.70	
21FEB89.CD	26.57	-146.9	11.62	-122.6	8.41	-119.3	4.79	-122.1
21FEB89.CE	16.59	-195.1	5.86	-102.7	4.12	-106.6	-1.07	-135.5
21FEB89.CF	22.11	-133.4	7.33	-143.4	-4.26	-105.3	-6.27	-140.9
21FEB89.CG	13.31	-158.6	4.60	-124.6	.96	-140.7	-3.00	-169.6
21FEB89.CH	19.02	-205.9	1.49	-57.1	-1.87	-146.4	-7.23	-179.5

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (PITCH)

RUN	0.20		0.50		0.90		1.40		2.40		4.20		9.00	
22FEB89.AJ	25.47	-78.2	17.83	-105.5	9.45	-114.0	5.89	-128.2	-.42	-145.9	-6.28	-156.2	-9.34	-223.9
22FEB89.AK	22.06	-96.8	15.02	-105.6	10.38	-115.7	5.44	-134.8	-1.74	-155.1	-6.74	-160.3	-9.63	-221.7
22FEB89.AL	26.86	-91.1	13.76	-100.6	9.91	-120.2	4.43	-121.6	-1.39	-147.1	-5.47	-156.4	-11.16	-241.1
22FEB89.AM	22.83	-105.7	11.94	-94.5	9.00	-110.0	3.77	-125.3	-.55	-125.8	-4.55	-157.5	-9.11	-269.8
22FEB89.AN	20.76	-120.3	11.90	-109.3	7.14	-120.4	3.13	-136.2	-3.91	-157.7	-5.20	-187.6	-8.63	19.1
22FEB89.AO	23.13	-103.4	9.82	-115.4	5.99	-113.2	1.51	-134.5	-2.60	-157.1	-4.78	-180.2	-9.38	11.7
22FEB89.AT	16.40	-121.4	11.01	-102.6	5.22	-106.7	1.99	-118.5	-.48	-129.6	-6.23	-155.1	-6.45	-245.2
22FEB89.AU	20.34	-131.4	9.76	-99.9	4.62	-105.8	1.82	-119.7	-3.89	-127.5	-6.43	-151.5	-6.95	-243.6
22FEB89.AW	16.43	-117.1	8.47	-107.8	5.28	-117.0	.98	-124.8	-2.94	-146.7	-5.46	-182.4	-6.43	16.4
22FEB89.AX	18.69	-97.4	7.69	-96.1	3.33	-112.9	.80	-120.0	-4.40	-150.0	-6.45	-181.6	-6.68	22.7
22FEB89.AY	15.61	-104.4	7.33	-98.2	4.95	-116.7	1.24	-113.4	-4.21	-134.1	-9.62	-137.2	-6.89	-213.0
22FEB89.AZ	22.23	-116.7	10.80	-118.2	5.41	-108.6	-.12	-127.1	-4.48	-116.9	-9.91	-138.7	-7.95	-214.6
22FEB89.BA	17.04	-95.7	8.34	-100.3	2.85	-104.2	-.46	-124.5	-2.46	-148.8	-5.30	-181.2	-5.94	16.9
22FEB89.BB	15.36	-110.7	9.79	-98.9	5.16	-112.4	1.39	-128.9	-5.14	-162.9	-5.44	-178.0	-4.70	11.1
22FEB89.CW	28.92	-144.5	13.76	-111.0	9.16	-106.8	6.19	-122.0	.41	-132.2	-5.11	-157.6	-5.75	-236.0
22FEB89.CX	21.53	-111.2	12.61	-97.2	8.09	-116.8	5.10	-118.6	.72	-142.3	-5.05	-151.3	-6.15	-231.9
22FEB89.CY	21.96	-137.9	13.36	-96.4	8.03	-112.5	3.77	-119.4	-3.25	-115.6	-4.72	-146.5	-7.42	-235.2
22FEB89.CZ	14.96	-108.5	9.27	-110.9	7.51	-118.8	2.96	-117.9	-1.75	-140.4	-6.92	-150.3	-6.62	-235.4

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (ROLL)

RUN	0.30		0.40		0.70		1.80		3.00		4.00		7.00	
22FEB89.AP	15.57	-61.8	16.76	-44.5	9.89	-92.7	2.17	-150.3	-2.48	-162.4	-4.28	-183.5	-7.43	80.6
22FEB89.AQ	11.66	-44.0	15.80	-106.6	9.29	-114.8	1.02	-145.3	-2.15	-168.4	-5.75	-189.6	-9.68	-256.2
22FEB89.AR	12.25	-13.5	11.55	-82.6	13.80	-161.3	.59	-153.2	-4.13	-194.1	-13.67	85.7	-16.42	77.2
22FEB89.AS	7.46	-10.7	7.22	-123.3	8.70	-109.2	-1.27	-158.4	-4.01	-172.5	-9.18	-208.9	-15.88	-269.6
22FEB89.AT	8.05	-82.4	18.59	-110.9	6.41	-118.0	-1.44	-141.8	-3.58	-163.9	-4.75	-171.7	-7.57	68.5
22FEB8Y.AU	14.77	-53.5	8.71	-62.7	11.97	-92.2	-.28	-131.7	-3.37	-166.0	-5.00	-192.6	-8.55	68.2
22FEB89.AW	17.06	-54.0	16.26	-28.0	5.71	-92.6	-2.43	-129.1	-5.87	-132.7	-8.37	-127.8	-6.73	-240.5
22FEB89.AX	16.16	-122.0	8.80	-77.6	5.20	-90.7	-1.19	-127.5	-9.36	-162.5	-8.11	-172.1	-9.06	-209.7
22FEB89.AY	16.11	70.9	7.64	-66.1	2.06	-91.1	-.24	-142.3	-3.73	-191.9	-9.62	-232.8	-13.10	57.6
22FEB89.AZ	12.02	-63.5	7.48	-102.1	5.93	-106.9	-.11	-153.5	-2.20	-160.3	-7.51	-226.7	-13.06	51.4
22FEB89.BA	6.07	-71.7	8.49	-71.3	4.77	-78.9	-3.73	-122.8	-7.01	-154.4	-15.07	-191.2	-11.33	-216.6
22FEB89.BB	8.75	-57.7	9.50	-88.1	4.28	-101.3	-4.97	-125.0	-8.79	-153.9	-16.15	-181.6	-12.47	-253.8
22FEB89.CW	12.18	-75.2	17.32	-50.9	8.92	-110.0	-.32	-135.5	-6.40	-134.8	-10.24	-156.4	-9.48	-217.0
22FEB89.CX	20.02	-62.6	13.67	-47.8	9.00	-111.4	-.78	-133.6	-8.31	-141.8	-7.06	-151.7	-9.92	-221.0
22FEB89.CY	10.25	-37.1	11.69	-87.2	6.93	-99.5	-2.96	-136.0	-6.54	-130.4	-9.04	-202.9	-14.04	-217.7
22FEB89.CZ	6.73	-73.4	14.28	-67.7	8.55	-90.3	-3.95	-145.8	-8.80	-114.8	-10.92	-142.8	-10.72	-256.2

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (SPEED)

RUN	0.10		0.30		0.50		0.70	
22FEB89.BA	13.05	-142.9	1.73	-143.8	-2.52	-157.2	-4.47	-161.2
22FEB89.BB	20.52	-58.4	8.28	-142.6	-4.35	-148.0	-5.90	-147.2
22FEB89.CY	11.18	-172.5	2.30	-130.0	-.77	-118.6	-3.68	-118.9
22FEB89.CZ	16.10	-126.3	2.32	-142.2	1.78	-140.0	-.34	-146.8

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (PITCH)

RUN	0.20		0.50		0.90		1.40		2.40		4.20		9.00	
22FEB89.CA	16.42	-92.9	11.42	-86.3	8.82	-95.1	5.59	-111.9	-1.26	-130.7	-4.70	-153.8	-5.53	-234.7
22FEB89.CB	20.48	-104.7	11.20	-96.2	8.57	-93.1	5.65	-114.0	-1.92	-126.2	-5.04	-143.1	-5.24	-239.1
22FEB89.CC	19.28	-76.7	10.13	-103.4	6.93	-99.3	3.37	-130.2	-2.63	-151.4	-4.83	-169.8	.44	16.3
22FEB89.CD	18.68	-37.5	9.79	-96.9	6.19	-104.9	1.87	-120.4	-3.41	-147.1	-4.72	-164.2	-1.93	26.3
22FEB89.CI	16.95	-91.2	9.78	-87.3	6.62	-94.9	6.25	-112.3	-.24	-132.2	-5.09	-150.0	-3.48	-233.8
22FEB89.CJ	18.91	-120.2	10.13	-88.1	7.03	-93.9	5.38	-115.1	.08	-126.8	-5.12	-145.7	-3.21	-240.5
22FEB89.CK	18.63	-94.2	12.57	-102.4	8.94	-116.3	3.57	-134.1	-3.01	-151.0	-4.66	-166.5	1.52	40.4
22FEB89.CL	13.29	-78.0	9.19	-90.8	7.43	-90.4	3.29	-129.3	-3.12	-148.7	-5.79	-161.6	.76	50.2
22FEB89.CM	18.72	-74.8	7.46	-111.5	6.08	-102.8	-.48	-111.6	-4.50	-120.1	-11.35	-132.4	-6.27	-202.8
22FEB89.CN	16.70	-90.2	8.56	-98.7	5.32	-112.0	1.74	-115.9	-3.83	-133.8	-9.30	-131.1	-6.59	-193.4
22FEB89.CO	10.65	-126.0	3.50	-98.3	2.01	-94.8	.67	-105.7	-6.19	-141.2	-5.37	-158.5	5.90	41.3
22FEB89.CP	17.10	-114.4	9.75	-73.7	4.83	-92.4	2.18	-108.9	-2.44	-134.1	-4.77	-154.4	3.87	47.1
22FEB89.CQ	9.77	-111.2	2.17	-86.4	-.56	-94.1	-3.21	-115.1	-5.48	-147.5	-18.72	-143.7	-4.61	-16.9
22FEB89.CR	8.13	-93.1	4.87	-92.4	.13	-91.3	-1.33	-112.1	-9.50	-137.2	-16.28	-157.9	-4.36	-18.5
22FEB89.CS	30.43	-135.0	9.50	-88.5	4.98	-90.6	2.68	-96.2	-3.89	-141.5	-9.34	-150.3	-6.22	-232.3
22FEB89.CT	15.80	-120.9	6.18	-84.1	4.45	-77.6	5.20	-66.9	-4.78	-140.8	-8.99	-146.7	-5.06	-242.2
22FEB89.CU	17.17	-84.1	6.34	-91.8	6.86	-106.3	3.18	-123.0	-5.80	-151.1	-7.19	-177.9	-2.98	20.9
22FEB89.CV	15.31	-87.0	7.32	-77.3	5.44	-91.1	1.53	-115.7	-5.58	-156.8	-7.09	-159.3	-1.04	29.2

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (ROLL)

RUN	0.30		0.40		0.70		1.80		3.00		4.00		7.00	
22FEB89.CE	17.30	-101.8	13.85	-76.2	11.37	-88.5	.99	-121.8	-5.11	-132.4	-4.92	-156.6	-8.57	-188.6
22FEB89.CF	15.24	-81.8	13.14	-81.2	9.71	-99.1	.70	-115.4	-3.05	-141.0	-5.40	-146.8	-9.06	-201.4
22FEB89.CG	5.94	-69.1	9.95	-103.2	5.49	-97.6	-2.01	-139.1	-5.72	-185.3	-7.93	-224.2	-16.02	44.3
22FEB89.CH	7.83	-51.4	15.58	-102.8	3.58	-105.7	-1.39	-135.5	-3.30	-180.5	-5.65	-218.3	-14.66	45.5
22FEB89.CI	12.89	-52.8	11.46	-39.1	6.79	-100.5	-1.27	-112.9	-5.71	-137.4	-6.18	-149.7	-8.96	-220.3
22FEB89.CJ	11.22	-49.0	9.85	-80.2	6.83	-70.3	-1.04	-124.4	-4.62	-143.6	-9.09	-161.5	-10.52	-213.0
22FEB89.CK	14.97	-25.7	10.84	-79.9	6.51	-96.6	-2.82	-113.8	-6.27	-157.3	-7.83	-144.3	-10.33	-226.4
22FEB89.CL	7.42	-76.5	7.32	-84.7	5.72	-84.0	-5.83	-109.6	-8.73	-147.0	-12.62	-130.4	-11.14	-235.7
22FEB89.CM	14.37	-95.1	6.97	-71.5	6.73	-82.9	-2.60	-154.8	-9.37	-178.9	-8.18	-248.5	-15.23	12.1
22FEB89.CN	8.54	-22.0	2.25	-70.3	2.23	-93.9	-1.43	-155.8	-5.45	-233.3	-9.56	-242.8	-17.19	15.7
22FEB89.CO	-1.41	-44.0	6.60	-59.3	2.05	-91.1	-1.68	-152.8	-5.98	-188.6	-10.17	-231.3	-21.11	25.1
22FEB89.CP	11.42	-21.9	11.58	-22.1	4.96	-122.7	-5.79	-166.1	-9.15	-196.7	-18.90	-219.0	-17.66	1.2
22FEB89.CQ	6.51	-50.6	9.72	-49.9	2.12	-60.7	-3.62	-101.8	-7.24	-160.5	-7.55	-143.5	-11.16	-228.1
22FEB89.CR	5.93	-72.8	6.71	-70.7	6.51	-101.1	-4.83	-120.7	-7.25	-132.3	-11.36	-172.6	-12.36	-204.8
22FEB89.CS	7.10	-84.4	2.14	-52.2	1.76	-61.1	-5.75	-120.9	-8.42	-133.3	-7.01	-123.8	-10.28	-229.6
22FEB89.CT	9.89	-40.2	10.34	-63.9	4.96	-82.2	-2.91	-113.6	-4.93	-127.2	-5.72	-135.9	-9.71	-230.8
22FEB89.CU	9.74	-70.3	6.31	-70.4	3.50	-88.9	-2.07	-112.7	-6.73	-127.4	-9.24	-180.4	-9.28	-233.2
22FEB89.CV	12.01	-45.4	5.13	-46.2	.30	-89.4	-5.10	-114.1	-5.48	-143.5	-11.16	-144.2	-11.23	-241.9

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (SPEED)

RUN	0.10		0.30		0.50		0.70	
22FEB89.CS	16.92	-127.5	-2.28	-126.9	-7.99	-141.2	-14.92	-99.8
22FEB89.CT	9.26	-125.8	-2.58	-128.6	-12.24	-148.9	-10.91	-174.4
22FEB89.CU	10.84	-151.9	-3.36	-112.7	-9.30	-139.7	-12.53	-172.9
22FEB89.CV	13.44	-127.5	1.11	-127.7	-4.69	-127.6	-1.59	-129.0

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (PITCH)

RUN	0.20		0.50		0.90		1.40		2.40		4.20		9.00	
23FEB89.AA	19.30	-118.6	14.65	-116.5	9.90	-117.8	4.91	-139.2	-2.45	-146.2	-8.60	-164.4	-13.46	-247.6
23FEB89.AB	15.74	-133.3	9.64	-110.7	7.74	-99.9	2.53	-131.4	-2.25	-149.2	-6.90	-156.5	-11.95	-246.3
23FEB89.AC	18.42	-116.4	9.72	-105.3	4.28	-114.0	.43	-114.1	-5.63	-145.6	-4.63	-146.7	-16.57	-254.5
23FEB89.AD	17.25	-132.7	9.88	-102.2	4.24	-107.8	.45	-113.5	-3.08	-131.1	-6.36	-146.8	-15.23	-265.6
23FEB89.AI	9.49	-109.3	4.65	-87.3	1.94	-94.8	.34	-100.8	-2.97	-121.8	-8.94	-145.9	-7.94	-230.0
23FEB89.AJ	10.21	-103.0	4.76	-108.7	1.76	-96.7	-.65	-103.1	-5.75	-116.4	-8.21	-145.5	-7.89	-238.4
23FEB89.AK	16.73	-114.0	8.71	-91.9	5.98	-122.7	.93	-132.8	-7.03	-137.6	-9.67	-153.3	-12.99	-230.2
23FEB89.AL	11.77	-115.5	14.00	-103.3	6.73	-113.5	2.29	-126.6	-2.64	-143.3	-9.35	-154.4	-15.17	-246.0
23FEB89.AM	18.71	-102.7	10.51	-94.6	4.33	-112.5	1.21	-111.2	-.64	-104.4	-8.00	-143.6	-14.77	78.4
23FEB89.AN	19.80	-152.2	8.99	-91.5	4.30	-103.9	1.47	-117.7	-2.84	-131.7	-6.32	-144.0	-13.90	82.9

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (ROLL)

RUN	0.30		0.40		0.70		1.80		3.00		4.00		7.00	
23FEB89.AE	20.13	-65.6	20.90	-100.0	15.46	-112.6	2.58	-131.0	-1.91	-148.5	-5.31	-165.0	-10.68	-192.6
23FEB89.AF	14.17	-107.0	17.40	-97.7	10.75	-111.4	.71	-133.3	-4.56	-152.3	-7.05	-158.8	-13.55	-205.1
23FEB89.AG	10.83	-84.2	15.07	-47.5	9.18	-95.5	-.22	-155.0	-4.09	-200.1	-9.83	-214.6	-17.31	-248.2
23FEB89.AH	10.60	-59.1	4.45	-56.0	8.58	-104.9	1.11	-136.4	-3.60	-195.3	-8.48	-203.7	-14.83	-266.8
23FEB89.AI	11.28	-27.1	22.99	-198.3	6.10	-106.7	1.32	-152.3	-7.94	-212.0	-7.12	-193.5	-17.61	60.5
23FEB89.AJ	7.11	-113.4	9.91	11.4	5.01	-119.2	.40	-151.4	-1.46	-198.0	-11.54	-249.6	-16.83	64.6

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (SPEED)

RUN	0.10		0.30		0.50		0.70	
23FEB89.AK	18.09	-107.9	4.88	-130.2	-1.93	-106.5	-4.03	-120.9
23FEB89.AL	17.74	-126.3	4.13	-126.5	-.51	-128.6	-3.53	-143.3
23FEB89.AM	15.72	-106.3	2.41	-141.2	.30	-134.8	-3.13	-153.1
23FEB89.AN	17.52	-170.2	7.75	-150.8	-5.42	-155.1	-7.82	-239.4

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (PITCH)

RUN	0.20		0.50		0.90		1.40		2.40		4.20		9.00	
23FEB89.BA	25.20	-83.9	15.44	-100.6	9.95	-108.1	6.23	-119.3	.96	-133.3	-4.95	-146.5	-8.25	-195.3
23FEB89.BB	23.86	-111.8	16.18	-116.2	12.08	-113.9	7.67	-126.3	1.28	-139.0	-4.34	-151.4	-8.25	-192.9
23FEB89.BC	21.47	-129.2	10.95	-104.3	6.47	-113.1	3.00	-119.2	-1.35	-143.9	-3.49	-157.0	-3.71	37.7
23FEB89.BD	19.97	-96.8	12.02	-108.6	7.95	-114.1	4.32	-123.9	-2.16	-145.8	-4.25	-157.5	-2.63	27.9
23FEB89.BE	13.15	-90.1	6.63	-104.0	.85	-114.5	-.02	-115.3	-3.21	-139.5	-8.94	-174.7	-10.70	-14.1
23FEB89.BF	14.77	-114.2	8.27	-107.6	2.71	-107.1	.34	-121.1	-3.72	-155.1	-6.81	-169.9	-3.66	-30.0
23FEB89.BK	23.41	-132.4	14.49	-115.5	8.20	-119.8	3.19	-133.3	-3.40	-136.5	-8.84	-144.5	-8.35	-181.6
23FEB89.BL	20.40	-93.9	12.71	-103.2	7.62	-120.4	2.54	-128.6	-2.87	-138.0	-7.68	-139.0	-8.09	-182.9
23FEB89.BM	19.43	-80.8	14.79	-112.4	8.27	-118.0	4.02	-128.6	-3.15	-135.7	-8.66	-141.3	-8.50	-181.9
23FEB89.BN	18.57	-102.5	7.10	-109.8	1.68	-106.6	-.21	-111.9	-3.17	-133.3	-7.32	-177.3	-4.02	3.2
23FEB89.BO	12.94	-112.7	7.63	-111.0	.70	-109.3	-1.77	-112.5	-5.81	-127.8	-6.30	-158.0	-1.74	7.5
23FEB89.BP	14.73	-104.9	7.56	-112.4	4.64	-112.1	2.31	-105.8	-2.91	-136.7	-5.48	-157.5	1.80	52.9
23FEB89.BQ	19.32	-87.4	10.64	-96.5	4.57	-109.1	2.09	-118.4	-2.25	-144.8	-5.28	-149.8	1.04	65.3
23FEB89.BR	18.80	-61.5	11.06	-94.1	4.08	-101.1	2.07	-113.6	-2.71	-139.6	-4.98	-153.2	2.82	55.0
23FEB89.BS	11.29	-95.4	4.48	-113.1	-.90	-107.8	-3.30	-104.6	-4.74	-130.7	-8.91	-164.8	-.48	-20.7
23FEB89.BT	20.60	-149.4	6.65	-121.8	-.95	-111.2	-3.30	-100.3	-2.85	-121.3	-10.52	-146.7	-1.43	-1.9
23FEB89.BV	15.60	-96.7	19.45	-170.7	7.04	-116.1	3.82	-124.2	-2.51	-156.3	-9.84	-144.3	-9.78	-192.4
23FEB89.BW	32.97	-174.4	13.39	-98.0	9.90	-116.6	4.54	-122.1	-3.28	-133.2	-13.14	-141.6	-9.49	-187.2
23FEB89.BX	15.80	-81.8	11.16	-117.0	3.13	-103.4	-1.94	-120.0	-.95	-137.2	-5.11	-178.2	-4.48	10.6
23FEB89.BY	18.78	-163.5	7.68	-102.3	3.12	-99.5	3.02	-118.9	-1.93	-144.1	-6.24	-231.7	-11.11	65.8
23FEB89.CD	13.75	-46.4	18.37	-115.4	8.12	-132.6	3.53	-137.3	-3.26	-130.4	-6.70	-149.3	-7.74	-188.1
23FEB89.CE	31.95	-196.3	17.50	-118.0	10.83	-117.7	5.13	-131.5	-1.35	-142.3	-7.18	-145.5	-7.36	-196.8

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (ROLL)

RUN	0.30		0.40		0.70		1.80		3.00		4.00		7.00	
23FEB89.BG	19.11	-139.4	14.90	-56.4	8.66	-110.6	1.03	-121.0	-5.09	-158.8	-6.30	-174.5	-9.20	-218.2
23FEB89.BH	12.64	-64.2	16.87	-61.7	8.57	-94.3	.53	-115.0	-4.00	-157.0	-7.11	-168.6	-7.51	-222.6
23FEB89.BI	12.20	-88.1	16.16	-53.7	6.24	-122.1	-1.43	-153.2	-5.36	-195.1	-7.58	-219.3	-13.08	52.7
23FEB89.BJ	14.20	-82.7	16.90	-79.2	6.13	-84.7	-.03	-150.8	-6.35	-192.2	-8.22	-246.8	-16.86	41.3
23FEB89.BK	15.40	-103.0	9.82	-107.9	8.32	-105.3	-1.19	-127.3	-4.38	-147.2	-7.59	-169.6	-8.48	-246.3
23FEB89.BL	18.14	-84.4	10.89	-73.1	9.68	-108.4	-2.03	-133.3	-4.23	-144.4	-5.37	-162.4	-5.80	-258.2
23FEB89.BM	11.94	-116.1	9.25	-96.5	5.96	-100.5	-1.47	-127.7	-6.27	-144.1	-7.57	-178.3	-7.35	-253.7
23FEB89.BN	13.09	-93.8	18.38	-113.3	3.81	-113.6	-4.84	-133.3	-9.64	-173.3	-9.20	-162.7	-9.91	-267.3
23FEB89.BO	13.74	-55.2	11.00	-79.2	8.11	-91.6	-2.41	-130.0	-6.63	-158.1	-8.25	-177.7	-7.33	-266.1
23FEB89.BP	15.12	-139.9	9.71	-103.5	7.33	-121.9	-2.92	-131.4	-8.28	-167.1	-8.21	-173.9	-9.85	-256.5
23FEB89.BQ	17.05	-69.3	13.97	-130.1	5.74	-99.3	-.03	-130.8	-6.48	-135.6	-5.19	-164.1	-5.95	-254.3
23FEB89.BR	11.78	-45.6	9.79	-105.9	7.33	-104.3	-3.57	-130.7	-9.70	-137.0	-9.83	-170.6	-8.78	-248.2
23FEB89.BS	10.81	-147.2	5.60	-126.0	6.19	-100.6	-1.93	-168.8	-13.06	70.0	-7.03	-266.4	-15.68	-2.1
23FEB89.BT	12.24	-58.3	4.07	-52.0	9.62	-99.6	-1.12	-158.8	-7.34	-210.2	-11.19	-245.3	-11.86	29.3
23FEB89.BZ	8.11	-71.9	4.61	-54.8	5.88	-89.7	-.27	-116.6	-4.31	-148.8	-7.51	-138.9	-6.80	-232.8
23FEB89.CA	24.83	-63.5	8.32	-121.7	14.07	-68.5	2.81	-135.3	-5.00	-152.0	-6.10	-184.1	-6.67	-238.8
23FEB89.CB	5.95	-100.3	56.11	-169.1	8.48	-100.2	-1.31	-146.8	-4.83	-215.9	-10.15	-246.1	-18.25	18.6
23FEB89.CC	5.82	31.5	6.97	-58.7	5.66	-116.4	-1.85	-148.4	-5.26	-198.0	-14.99	-203.6	-19.32	57.5
23FEB89.CD	13.17	-163.4	10.55	-71.9	3.50	-112.6	-4.53	-127.8	-4.02	-153.8	-6.99	-179.1	-9.77	-245.8
23FEB89.CE	17.47	-47.9	11.24	-82.9	7.57	-109.3	-1.54	-127.4	-8.41	-170.5	-6.86	-176.7	-7.57	86.7

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (SPEED)

RUN	0.10		0.30		0.50		0.70	
23FEB89.BU	19.91	-245.4	12.02	-250.0	2.91	-154.4	-4.92	-218.1
23FEB89.BV	14.93	-154.3	4.05	-131.4	-3.46	-149.7	-3.92	-166.5
23FEB89.BW	13.87	-165.3	9.58	-142.7	1.19	-149.7	.41	-150.8
23FEB89.BX	14.41	-121.3	5.04	-141.0	-2.90	-144.4	-4.12	-167.2
23FEB89.BY	15.45	-174.0	1.73	-139.1	-.55	-149.2	1.30	-140.4
23FEB89.BZ	24.52	-104.6	8.45	-131.3	3.39	-101.7	-.86	-122.4
23FEB89.CA	16.96	-83.0	9.81	-82.1	3.87	-135.4	-3.58	-53.9
23FEB89.CB	20.70	-159.7	5.17	-132.9	-.30	-136.7	-.95	-137.6
23FEB89.CC	22.73	-161.8	5.94	-124.3	3.81	-130.7	.31	-147.7
23FEB89.CD	15.69	-42.7	5.11	-127.9	9.09	-179.9	2.45	-169.8
23FEB89.CE	16.43	-158.0	3.63	-126.3	-.38	-133.0	-6.96	-90.1

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (PITCH)

RUN	0.20		0.50		0.90		1.40		2.40		4.20		9.00	
24FEB89.AA	25.87	-139.9	19.23	-116.2	13.11	-119.2	7.60	-133.2	-.35	-142.3	-4.42	-150.5	-7.70	-192.8
24FEB89.AB	31.53	-86.3	21.40	-115.0	12.10	-113.5	7.59	-138.7	.98	-141.2	-4.09	-148.4	-7.07	-197.8
24FEB89.AC	17.16	-100.9	16.62	-94.0	9.94	-113.1	6.24	-129.4	.13	-135.1	-3.20	-146.1	-5.81	-217.0
24FEB89.AD	22.28	-76.2	14.03	-100.2	9.73	-106.9	6.08	-114.6	-.11	-131.9	-3.17	-143.0	-6.56	-223.7
24FEB89.AE	23.37	-84.7	15.29	-99.4	8.19	-110.2	3.61	-128.1	-1.21	-142.1	-2.67	-159.1	-1.96	56.9
24FEB89.AF	20.81	-89.3	14.54	-95.8	8.64	-112.0	3.15	-134.5	-1.63	-136.2	-3.40	-158.7	-2.14	50.5
24FEB89.AM	24.28	-83.5	12.87	-107.4	5.84	-110.5	2.69	-110.6	-5.13	-116.3	-4.37	-138.7	-4.90	-222.2
24FEB89.AN	23.86	-91.0	12.71	-103.1	8.67	-104.9	4.97	-107.7	-.78	-123.6	-2.11	-139.0	-4.07	-219.3
24FEB89.AO	4.77	-98.7	8.09	-125.2	.00	-107.3	-5.37	-106.2	-11.29	-96.2	-10.38	-121.9	-9.65	-197.0
24FEB89.AP	21.10	-167.3	7.51	-117.5	-.89	-114.8	-6.21	-109.0	-7.45	-111.4	-11.38	-118.5	-9.63	-190.2
24FEB89.AQ	27.20	-114.5	6.43	-114.4	.81	-111.7	-3.57	-106.0	-8.39	-111.4	-11.05	-127.7	-9.96	-198.0
24FEB89.AR	21.21	-92.6	10.40	-113.5	5.11	-113.2	3.11	-126.8	-3.69	-138.5	-3.87	-174.0	-4.52	35.5
24FEB89.AS	12.83	-97.5	13.55	-87.1	5.45	-110.4	1.29	-124.0	-2.66	-140.6	-3.69	-164.5	-2.81	34.9
24FEB89.AT	24.41	-84.3	12.23	-96.5	4.64	-114.1	1.31	-129.3	-5.48	-135.6	-3.78	-160.4	-2.51	26.3
24FEB89.AU	32.06	-258.6	10.50	-127.8	4.07	-116.4	-.67	-127.1	-4.29	-124.4	-9.47	-129.1	-7.67	-196.3
24FEB89.AV	26.34	-133.6	9.86	-104.4	4.66	-121.9	-.71	-120.5	-6.02	-129.4	-9.11	-136.8	-9.63	-197.1

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (ROLL)

RUN	0.30		0.40		0.70		1.80		3.00		4.00		7.00	
24FEB89.AG	16.90	-54.3	15.66	-56.7	13.07	-119.1	3.87	-128.0	-1.47	-133.8	-2.07	-164.0	-9.32	-184.9
24FEB89.AH	16.82	-77.3	14.57	-82.0	13.83	-103.5	1.28	-122.5	-3.69	-138.9	-3.86	-155.6	-9.35	-189.2
24FEB89.AI	15.23	-127.9	22.03	-54.3	8.42	-97.9	-.60	-144.2	-3.13	-196.8	-8.32	-214.8	-15.20	74.4
24FEB89.AJ	2.39	-76.7	13.68	-150.7	10.70	-104.2	-.09	-153.3	-3.69	-200.3	-6.21	-234.6	-13.39	37.2
24FEB89.AK	18.17	-98.8	17.18	-88.9	11.93	-108.7	-.64	-122.4	-1.28	-149.8	-3.57	-172.9	-9.18	-250.1
24FEB89.AL	15.35	-95.5	13.63	-91.0	10.43	-98.6	-.17	-128.2	-3.27	-150.0	-3.60	-171.4	-10.36	-244.5
24FEB89.AM	13.65	-126.0	14.02	-53.9	14.80	-79.1	5.57	-132.5	-.49	-112.3	-6.09	-146.1	-5.70	-183.1
24FEB89.AN	21.75	-93.5	32.37	-103.4	13.77	-94.3	2.49	-112.1	-.37	-127.1	-.12	-149.0	-3.76	-179.6
24FEB89.AO	8.53	26.6	5.21	-113.3	8.63	-117.2	-.44	-138.7	1.55	-212.4	-11.23	-237.4	-19.31	51.1
24FEB89.AP	10.01	-80.5	.51	-65.0	12.39	-119.7	-2.54	-117.2	-2.27	-212.9	-14.93	-177.0	-15.84	-243.3
24FEB89.AQ	5.89	-108.9	3.66	-108.1	8.34	-131.1	-2.85	-155.3	-3.66	-185.4	-9.09	-198.5	-19.84	54.9
24FEB89.AR	19.17	-64.4	23.04	-152.0	10.43	-94.3	1.29	-107.4	-1.06	-153.5	-1.97	-154.1	-3.70	-187.5
24FEB89.AS	33.74	50.6	11.58	-27.8	11.11	-94.0	2.56	-139.9	-2.44	-134.9	-1.90	-151.4	-3.69	-197.0
24FEB89.AT	17.39	-80.6	31.40	-22.5	10.70	-94.3	3.63	-119.4	-.57	-144.8	-7.35	-121.1	-4.32	-187.8
24FEB89.AU	10.72	14.3	8.85	-66.7	14.51	-29.6	3.45	-135.5	-2.51	-153.5	-2.76	-143.4	-2.75	-236.0
24FEB89.AV	14.44	-132.1	10.70	-65.3	9.03	-103.2	.12	-119.5	-.67	-155.6	-4.76	-170.6	.32	71.4

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (PITCH)

RUN	0.20		0.50		0.90		1.40		2.40		4.20		9.00	
24FEB89.DA	5.75	-129.6	-1.28	-117.2	-3.13	-118.0	-14.47	-123.1	2.01	-263.3	-8.43	-161.9	-15.84	-79.3
24FEB89.DB	18.05	-139.2	10.34	-127.1	7.22	-119.8	1.20	-142.2	-4.03	-164.7	-7.39	-186.5	-13.57	8.7
24FEB89.DC	20.25	-100.2	10.34	-110.3	5.92	-113.3	2.87	-104.7	-3.49	-137.0	-6.27	-141.3	-13.83	..4
24FEB89.DD	14.19	-123.4	8.02	-102.2	6.10	-114.5	2.05	-120.2	-6.30	-131.1	-6.33	-161.1	-16.96	67.7
24FEB89.DK	18.25	-131.5	10.06	-106.0	4.37	-108.4	1.00	-118.2	-4.25	-135.4	-8.39	-170.9	-10.23	-242.6
24FEB89.DL	15.34	-80.8	9.99	-111.4	5.67	-111.3	1.97	-119.6	-6.03	-133.2	-8.89	-164.9	-10.84	-255.1
24FEB89.DM	19.51	-132.8	10.07	-96.2	4.24	-101.8	.83	-106.2	-1.32	-133.8	-5.25	-150.9	-9.39	82.4
24FEB89.DN	18.52	-153.6	8.22	-84.6	4.44	-115.8	.84	-113.5	-3.46	-135.1	-6.58	-149.2	-10.32	86.4
24FEB89.DO	11.72	-64.3	5.66	-104.2	.61	-89.0	-.46	-77.4	-3.99	-109.1	-5.45	-142.9	-8.06	76.6
24FEB89.DP	10.69	-110.6	2.05	-95.9	.03	-88.0	-3.06	-101.4	-3.74	-92.3	-6.16	-152.4	-7.64	86.2
24FEB89.DR	13.21	-69.8	15.42	-69.4	4.61	-127.2	-.71	-143.9	-11.79	-167.3	-12.28	-172.9	-15.46	-235.5
24FEB89.DS	19.46	-103.2	12.36	-106.2	6.73	-128.6	3.05	-142.5	-4.44	-155.8	-10.33	-174.0	-12.84	-223.0
24FEB89.DT	21.72	-93.2	15.35	-115.7	8.94	-131.2	4.42	-145.3	-4.40	-161.2	-10.78	-159.1	-13.33	-218.6
24FEB89.DU	17.82	-129.1	10.14	-111.6	3.61	-108.9	1.71	-135.5	-4.36	-162.9	-7.19	-198.4	-9.91	27.1
24FEB89.DV	16.42	-61.9	14.63	-101.0	3.77	-108.5	.37	-133.9	-4.02	-163.0	-6.83	-190.1	-10.30	27.6
24FEB89.EB	18.84	-150.2	8.18	-83.1	3.35	-101.9	1.19	-96.3	-3.64	-124.0	-6.49	-148.1	-6.21	-249.0
24FEB89.EC	19.91	-138.9	6.91	-98.2	2.89	-102.5	-1.52	-105.8	-2.61	-118.8	-7.28	-154.3	-8.72	-258.5
24FEB89.ED	15.17	-101.9	8.18	-89.2	2.56	-93.3	.39	-102.2	-2.70	-120.1	-5.20	-157.1	-9.35	89.8
24FEB89.EE	15.85	-121.7	6.13	-91.5	1.71	-102.3	-.02	-91.7	-4.01	-129.2	-4.52	-142.4	-11.94	62.1
24FEB89.EF	16.06	-125.5	10.07	-94.9	5.86	-102.2	3.63	-120.7	-1.99	-147.6	-7.38	-157.0	-7.97	-254.6
24FEB89.EG	16.98	-101.6	7.71	-97.8	5.11	-109.4	2.04	-122.8	-2.81	-150.5	-7.91	-157.7	-8.64	-264.7
24FEB89.EH	17.27	-106.5	7.94	-96.8	3.19	-92.3	-1.80	-88.0	.89	-109.0	-7.07	-139.2	-9.05	62.9
24FEB89.EI	21.21	-132.5	10.96	-89.2	3.39	-94.3	-2.22	-75.1	-2.57	-140.2	-5.28	-150.7	-4.92	57.4

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (ROLL)

RUN	0.30		0.40		0.70		1.80		3.00		4.00		7.00	
24FEB89.DE	14.39	-67.3	16.13	-84.1	9.82	-103.6	.76	-127.8	-3.92	-159.5	-7.07	-165.8	-12.83	-221.3
24FEB89.DF	19.50	-74.9	14.79	-80.7	12.30	-92.0	.72	-128.5	-3.99	-159.7	-6.49	-167.0	-9.93	-215.4
24FEB89.DG	12.92	-88.7	15.32	-84.9	8.80	-117.8	.23	-144.3	-4.26	-178.9	-6.47	-201.4	-13.21	82.0
24FEB89.DH	18.32	-39.6	12.59	-66.3	8.63	-116.9	.02	-147.8	-3.95	-180.0	-8.24	-212.7	-13.87	70.9
24FEB89.DI	13.03	-61.6	25.84	-14.0	10.10	-115.7	-.86	-153.5	-5.48	-199.2	-8.83	-212.9	-17.19	84.7
24FEB89.DJ	7.13	-68.1	15.95	-63.2	9.62	-79.9	.46	-151.4	-4.13	-197.6	-7.83	-204.5	-16.57	81.1
24FEB89.DK	15.01	-83.5	4.43	-81.4	7.28	-96.1	-.56	-124.8	-5.00	-148.2	-9.92	-157.4	-10.32	-236.4
24FEB89.DL	8.31	-80.7	9.54	-73.7	6.97	-96.6	-3.40	-136.4	-12.14	-150.8	-17.58	-203.1	-11.00	-242.9
24FEB89.DM	7.28	-78.0	6.69	-76.2	7.24	-96.5	-2.57	-126.6	-12.99	-151.3	-11.35	-198.3	-12.47	-252.3
24FEB89.DN	12.66	-82.6	11.07	-74.4	7.99	-83.0	-2.42	-130.8	-7.25	-162.1	-9.06	-189.2	-9.44	-244.0
24FEB89.DO	8.55	-111.4	18.05	-5.7	15.52	-93.2	-1.35	-150.3	-3.55	-196.6	-9.97	-238.6	-18.04	-265.2
24FEB89.DP	4.65	-76.2	13.39	-91.5	1.17	-61.1	-3.32	-157.3	-11.99	-151.5	-11.19	-212.1	-20.64	56.6
24FEB89.DW	19.98	-24.4	11.15	-48.7	7.99	-97.3	-1.13	-130.0	-5.79	-157.7	-7.86	-172.6	-12.71	-216.1
24FEB89.DX	14.22	-14.1	10.62	-93.2	14.06	-75.7	.01	-130.2	-5.91	-134.7	-7.05	-142.1	-13.71	-197.0
24FEB89.DY	4.19	-.3	6.37	-66.2	4.60	-86.2	-1.17	-152.0	-11.39	-126.4	-12.81	-187.7	-17.00	-264.7
24FEB89.DZ	21.80	-39.0	19.66	-68.6	4.98	-106.8	-2.06	-145.2	-12.25	-154.5	-9.65	-233.8	-18.61	31.3
24FEB89.EA	13.32	-65.4	9.36	-79.0	7.68	-59.1	-1.14	-143.0	-4.50	-160.7	-13.50	-74.3	-11.63	89.5
24FEB89.EB	5.75	-57.4	7.23	8.4	5.94	-86.6	-.68	-146.4	-6.90	-175.3	-12.41	-262.3	-21.30	54.8
24FEB89.EC	28.89	-183.6	11.46	-111.1	4.76	-112.9	-1.27	-146.3	-6.18	-172.7	-14.37	-207.2	-19.39	16.5
24FEB89.ED	9.37	-80.0	5.67	-77.4	6.05	-88.7	-4.68	-120.2	-10.56	-123.7	-11.83	-165.3	-10.70	-240.0
24FEB89.EE	9.08	-74.6	8.94	-92.4	2.25	-105.0	-5.84	-137.3	-9.45	-125.4	-11.31	-142.8	-18.41	-252.5
24FEB89.EF	12.07	-20.5	5.02	-85.9	4.69	-98.8	-.01	-126.6	-9.33	-188.8	-7.99	-208.7	-14.33	37.5
24FEB89.EG	6.44	-43.8	11.22	-81.1	4.91	-84.3	-3.78	-134.4	-3.63	-152.2	-6.73	-197.8	-14.67	29.6
24FEB89.EH	-2.04	-20.4	9.93	-103.0	4.10	-96.0	-1.90	-163.6	-8.18	-213.7	-12.72	-232.8	-22.97	25.7
24FEB89.EI	3.50	-103.5	13.94	-92.6	9.54	-65.4	-2.05	-155.5	-11.49	-212.0	-17.90	-255.9	-25.50	13.5

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (SPEED)

RUN	0.10		0.30		0.50		0.70	
24FEB89.DQ	29.66	-228.2	16.72	-164.3	14.15	-126.9	5.24	-127.1
24FEB89.DR	13.20	-118.2	5.53	-141.3	-1.23	-147.2	-1.51	-162.9
24FEB89.DS	17.15	-155.2	8.22	-168.4	-22.48	-221.2	-.80	-162.8
24FEB89.DT	19.12	-133.7	12.55	-131.6	1.83	-155.4	-6.34	-155.4
24FEB89.DU	15.96	-133.9	2.33	-124.0	1.04	-149.5	-.02	-160.7
24FEB89.DV	31.70	-234.3	4.80	-138.3	2.30	-137.6	-1.95	-134.7
24FEB89.DW	19.51	-238.9	8.52	-122.7	3.65	-109.3	-.78	-130.8
24FEB89.DX	21.53	-95.7	8.33	-111.2	4.36	-107.0	2.68	-80.8
24FEB89.DY	22.63	59.3	5.87	-135.0	1.89	-128.7	-2.52	-139.8
24FEB89.DZ	18.26	-155.3	5.89	-109.5	9.05	-126.3	11.25	-141.3
24FEB89.EA	17.64	-144.1	7.10	-123.7	3.03	-142.1	-.78	-129.5
24FEB89.EB	17.81	-187.6	8.77	-149.8	-.22	-115.2	-9.02	-180.0
24FEB89.EC	19.34	-109.7	7.11	-89.6	1.69	-137.2	-1.81	-161.6
24FEB89.ED	25.56	-103.3	2.11	-122.0	-1.84	-154.5	-10.29	-211.8
24FEB89.EE	11.29	-120.0	2.54	-136.0	.81	-102.5	-.62	-155.2
24FEB89.EF	13.16	-112.1	8.37	-105.6	1.15	-145.5	-1.05	-167.6
24FEB89.EG	16.40	-68.3	4.75	-129.8	-3.38	-151.1	-4.88	-153.5
24FEB89.EH	13.27	-157.3	1.92	-125.5	-.82	-154.3	-3.70	-167.2
24FEB89.EI	13.64	-103.2	5.30	-140.4	.77	-155.6	1.31	-96.9

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (PITCH)

RUN	0.20		0.50		0.90		1.40		2.40		4.20		9.00	
13MAR89.AA	24.21	-109.9	18.08	-104.7	13.19	-112.4	6.88	-129.2	.84	-149.2	-4.96	-154.3	-5.63	-202.4
13MAR89.AB	25.20	-83.4	17.05	-95.8	11.95	-109.4	7.57	-124.2	1.45	-140.8	-4.07	-151.3	-4.86	-199.4
13MAR89.AC	22.17	-86.9	13.01	-91.7	10.65	-94.8	7.46	-114.9	1.85	-128.3	-2.58	-149.6	-4.26	-232.6
13MAR89.AD	21.52	-86.5	15.36	-91.7	9.71	-93.2	6.24	-111.9	1.87	-130.4	-3.42	-148.2	-4.72	-225.8
13MAR89.AE	16.05	-98.9	10.37	-94.8	6.23	-88.9	2.96	-101.5	-.98	-130.0	-4.22	-133.3	-7.87	-264.5
13MAR89.AF	21.31	-114.0	12.50	-97.1	8.67	-107.2	4.04	-138.3	-2.38	-156.1	-4.75	-165.7	-2.12	51.6
13MAR89.AG	15.07	-91.9	10.70	-100.2	10.85	-98.1	3.73	-129.2	-1.78	-145.0	-4.23	-162.2	1.17	45.0
13MAR89.AH	16.31	-108.1	10.69	-90.5	7.32	-100.7	3.25	-129.5	-2.76	-149.0	-5.24	-156.5	1.65	36.8
13MAR89.AI	15.41	-99.5	8.19	-92.2	4.53	-100.1	.94	-121.3	-2.54	-145.6	-6.92	-168.4	-4.63	-11.0
13MAR89.AJ	14.44	-70.2	10.67	-88.3	4.52	-106.0	3.39	-119.7	-4.02	-140.6	-9.07	-173.0	-2.61	-55.2
13MAR89.AQ	23.30	-80.4	15.68	-105.5	11.77	-115.4	6.45	-139.4	-.56	-143.4	-6.81	-153.8	-7.64	-189.6
13MAR89.AR	20.42	-87.7	16.79	-113.7	12.55	-112.2	7.05	-142.0	.43	-149.0	-6.04	-147.4	-8.43	-200.4
13MAR89.AS	8.33	-13.9	7.21	-39.1	6.13	-52.3	4.24	-76.3	1.04	-120.3	-4.53	-141.0	-5.13	-188.2
13MAR89.AT	11.06	-30.4	8.86	-52.6	6.63	-53.3	7.15	-83.6	2.55	-121.0	-3.28	-143.8	-5.50	-190.6
13MAR89.AU	12.61	-22.4	9.14	-43.3	7.92	-53.9	6.48	-69.2	2.65	-124.7	-2.53	-143.7	-5.91	-194.9
13MAR89.AV	13.34	-29.8	9.88	-44.2	7.32	-59.7	6.11	-89.7	.01	-128.6	-5.00	-152.9	-1.52	-242.0
13MAR89.AW	9.92	-32.9	8.25	-49.4	5.80	-57.4	5.65	-101.7	-1.79	-139.4	-6.39	-147.6	-3.42	-232.3
13MAR89.BF	25.79	-106.6	12.98	-114.3	9.39	-111.6	5.14	-131.2	-2.93	-137.7	-7.40	-154.1	-9.61	-191.1
13MAR89.BG	20.21	-65.4	16.01	-99.0	12.61	-115.3	7.56	-143.6	.39	-141.5	-6.71	-148.5	-7.67	-202.6
13MAR89.BH	25.98	-108.0	17.47	-108.1	10.36	-115.7	6.36	-142.0	-1.44	-147.3	-7.03	-153.5	-7.66	-203.3
13MAR89.BI	26.44	-139.0	13.02	-99.2	8.59	-89.7	9.13	-126.9	1.57	-134.1	-3.10	-149.9	-3.37	-227.7
13MAR89.BJ	24.63	-56.5	12.95	-99.5	9.30	-84.8	7.55	-121.3	-1.70	-132.7	-4.06	-144.4	-3.09	-228.0
13MAR89.BK	15.41	-108.0	9.39	-95.1	6.66	-86.1	7.53	-81.9	-.68	-138.4	-4.30	-142.7	-4.31	-223.8
13MAR89.BL	17.54	-74.4	11.57	-94.7	8.90	-86.2	9.50	-108.1	.91	-141.9	-3.63	-145.7	-2.81	-220.2
13MAR89.BO	18.70	-108.2	12.79	-84.3	11.14	-67.3	13.26	-120.6	-.16	-134.5	-3.58	-145.6	-2.40	-220.4
13MAR89.BP	14.19	-111.8	12.89	-69.5	9.42	-79.8	9.91	-100.0	-1.87	-128.9	-4.49	-136.7	-2.12	-228.8
13MAR89.BQ	18.27	-81.4	9.54	-83.5	7.10	-73.8	5.53	-100.2	.29	-138.6	-3.41	-138.0	-2.15	-246.0
13MAR89.BR	16.96	-92.1	10.54	-90.4	7.04	-73.2	8.78	-99.7	1.62	-134.4	-4.48	-144.3	-2.76	-246.9
13MAR89.BS	15.20	-110.8	8.93	-94.4	7.42	-78.1	5.99	-113.8	-1.06	-139.1	-3.76	-134.3	-4.07	-251.1
13MAR89.BT	12.53	-105.5	6.35	-91.8	3.38	-69.8	5.65	-75.4	-2.16	-134.3	-5.82	-137.1	-3.91	-250.6
13MAR89.BU	17.38	-127.4	8.40	-78.2	4.88	-60.3	7.76	-72.9	.36	-131.7	-4.97	-146.0	-5.31	-253.7
13MAR89.BV	22.63	-99.0	10.07	-95.8	8.46	-94.6	5.32	-116.3	-.91	-141.4	-3.37	-149.3	-7.05	-252.8
13MAR89.BW	18.19	-91.5	12.24	-84.1	7.30	-81.0	6.29	-113.9	-1.36	-135.3	-3.38	-145.8	-4.96	-260.6
13MAR89.BX	17.04	-41.8	9.32	-77.9	5.06	-60.8	10.81	-113.5	.60	-125.5	-3.88	-140.1	-1.84	-239.1
13MAR89.BY	17.91	-107.5	7.68	-77.6	6.32	-58.4	11.10	-79.6	1.25	-141.8	-3.82	-145.5	-.17	-242.0
13MAR89.BZ	17.39	-113.7	7.76	-97.1	3.54	-91.8	2.83	-123.1	-4.56	-143.7	-6.74	-160.8	-3.61	-9.7
13MAR89.CA	14.24	-97.8	7.04	-97.4	3.43	-90.5	2.11	-125.8	-3.76	-144.3	-6.94	-164.9	-3.89	-20.3

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (ROLL)

RUN	0.30		0.40		0.70		1.80		3.00		4.00		7.00	
13MAR89.AK	15.38	-72.5	17.77	-78.1	10.70	-109.4	.82	-130.0	-3.28	-163.3	-5.53	-177.7	-9.11	-263.1
13MAR89.AL	18.50	-89.5	16.03	-76.3	10.31	-90.6	.47	-124.5	-3.76	-152.7	-4.59	-172.2	-8.05	-240.3
13MAR89.AM	11.33	-32.3	15.32	-29.8	10.35	-86.6	.38	-141.4	-4.11	-178.1	-7.29	-190.4	-12.82	-245.6
13MAR89.AN	19.92	-3.8	15.33	-71.7	9.07	-100.9	.11	-141.2	-4.46	-168.9	-8.21	-201.5	-12.57	-262.3
13MAR89.AO	3.12	8.8	-.69	-86.0	6.79	-97.4	.26	-131.1	-2.47	-181.8	-4.35	-220.3	-11.37	49.5
13MAR89.AP	6.81	-83.6	11.93	-75.5	6.87	-110.9	-1.55	-134.3	-3.41	-178.2	-6.73	-210.2	-15.39	52.9
13MAR89.AX	14.03	-72.1	11.93	-79.1	6.90	-94.8	.35	-124.5	-4.07	-139.1	-5.90	-163.7	-9.44	-237.9
13MAR89.AY	16.24	-53.2	14.13	-76.2	9.44	-103.1	2.01	-126.7	-3.27	-150.3	-5.36	-170.1	-10.38	-232.8
13MAR89.AZ	12.83	-41.8	14.57	-65.2	7.97	-110.8	-.33	-138.9	-7.06	-152.7	-8.84	-179.8	-12.48	-238.8
13MAR89.BA	7.58	-36.2	12.09	-66.6	9.63	-83.4	-.43	-140.[illegible]	-6.59	-164.0	-7.97	-190.7	-14.48	-241.1
13MAR89.BB	8.96	-83.0	11.11	-62.3	7.24	-90.1	-.90	-125.7	-4.12	-148.1	-6.58	-205.6	-13.97	66.7
13MAR89.BC	11.05	-72.3	11.01	-84.4	5.89	-86.9	-2.22	-134.8	-6.43	-172.3	-6.54	-201.9	-11.88	67.8
13MAR89.BD	13.38	-35.4	10.57	-84.9	8.16	-88.9	.33	-133.3	-4.85	-158.6	-7.25	-172.5	-12.65	-232.9
13MAR89.BE	9.33	-54.0	9.69	-50.7	7.02	-84.7	-.02	-122.5	-4.60	-147.7	-7.97	-179.4	-13.38	-222.2
13MAR89.BF	10.93	-64.1	7.53	-31.4	5.05	-72.6	-.68	-109.1	-6.24	-140.7	-7.79	-159.8	-8.61	-202.1
13MAR89.BG	9.47	-48.3	12.24	-76.6	7.61	-84.6	-1.25	-116.0	-6.19	-143.0	-6.53	-160.3	-7.65	-203.7
13MAR89.BH	15.56	-59.8	10.23	-56.0	5.88	-95.1	1.57	-111.4	-2.96	-136.8	-5.72	-155.7	-8.22	-207.7
13MAR89.BI	13.97	-44.0	10.84	-59.3	6.76	-91.8	-1.99	-130.2	-4.01	-163.7	-8.90	-186.2	-12.08	-266.5
13MAR89.BJ	8.79	-53.4	10.76	-79.9	6.74	-100.7	-1.23	-126.6	-4.44	-154.0	-7.71	-177.1	-12.08	74.6
13MAR89.BK	8.71	-47.3	9.45	39.6	7.51	-94.3	-1.36	-154.7	-8.12	-189.3	-11.56	-214.3	-16.36	79.7
13MAR89.BL	7.53	-8.7	2.95	-42.4	6.00	-115.1	-.28	-150.7	-6.64	-177.7	-10.82	-208.9	-15.12	59.3
13MAR89.BM	12.03	-63.8	8.80	-60.1	4.61	-86.7	-1.01	-118.4	-2.79	-153.1	-6.33	-167.1	-11.93	-236.3
13MAR89.BN	12.76	-64.7	7.48	-69.8	4.32	-93.1	-3.11	-121.7	-5.85	-144.2	-8.50	-176.0	-13.39	-245.2
13MAR89.BO	5.35	35.3	11.33	-53.8	4.68	-102.1	-2.01	-157.7	-8.08	-207.8	-11.30	-251.2	-17.04	14.6
13MAR89.BP	.90	-38.2	9.06	-24.7	6.09	-96.4	-1.88	-153.4	-5.39	-199.7	-10.39	-256.9	-17.45	19.8
13MAR89.BQ	8.79	-55.0	7.11	-9.0	5.29	-76.0	-3.13	-116.5	-2.72	-149.9	-5.86	-190.2	-10.10	76.3
13MAR89.BR	8.68	-82.7	13.36	-45.8	5.05	-93.6	-.88	-115.5	-3.08	-160.2	-7.03	-181.6	-13.08	-269.3
13MAR89.BS	9.98	-60.0	9.15	-70.0	3.67	-88.5	-1.67	-125.6	-5.50	-161.4	-7.50	-174.9	-10.53	80.0
13MAR89.BT	11.24	-21.2	7.64	22.6	8.20	-89.5	-1.83	-150.7	-8.44	-166.9	-9.42	-208.0	-19.68	69.8
13MAR89.BU	12.64	-16.7	3.64	-30.2	9.60	-57.5	-2.59	-150.3	-6.81	-181.7	-11.93	-217.1	-17.80	58.2
13MAR89.BX	8.26	-50.6	3.26	-25.2	6.20	-78.7	-1.27	-155.7	-5.31	-202.4	-11.98	-215.3	-16.26	23.5
13MAR89.BY	7.02	-2.7	6.43	-37.4	4.62	-119.2	-2.66	-152.7	-7.55	-200.1	-17.59	-246.6	-16.75	12.9
13MAR89.BZ	4.40	-34.0	10.66	-22.2	.97	-90.8	-4.27	-116.4	-5.21	-148.4	-6.30	-186.4	-11.66	72.6
13MAR89.CA	6.09	-79.8	4.82	-76.8	2.11	-68.7	-4.57	-124.0	-4.50	-156.4	-7.93	-199.7	-14.24	80.5
13MAR89.CB	-1.51	-26.3	1.96	-40.5	-1.80	-78.5	-6.02	-118.9	-13.90	-144.6	-12.04	-239.6	-21.76	67.5
13MAR89.CC	4.20	-63.5	5.22	-78.0	1.93	-106.1	-4.56	-124.9	-7.41	-149.5	-10.91	-178.1	-13.67	64.0
13MAR89.CD	5.86	-36.1	10.04	-91.2	8.99	-124.9	-5.15	-163.4	-12.12	-200.8	-12.62	-228.3	-22.35	56.5

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (PITCH)

RUN	0.20		0.50		0.90		1.40		2.40		4.20		9.00	
14MAR89.AE	19.12	-106.1	16.00	-84.9	9.66	-111.4	5.19	-132.0	-.22	-139.4	-6.27	-161.1	-5.74	-238.0
14MAR89.AF	21.68	-106.2	14.20	-96.9	11.89	-99.7	8.21	-122.2	.80	-143.6	-4.10	-152.9	-6.57	-231.2
14MAR89.AG	20.68	-103.5	10.42	-95.9	7.10	-104.0	3.42	-115.8	-3.89	-131.8	-5.17	-147.3	-7.76	-264.4
14MAR89.AH	18.40	-106.1	10.21	-93.4	7.32	-104.9	3.20	-123.1	-3.68	-134.8	-4.99	-144.5	-9.15	82.8
14MAR89.AI	22.11	-115.7	15.60	-91.4	9.34	-119.1	4.07	-145.9	-2.93	-158.8	-6.06	-176.3	-2.58	33.9
14MAR89.AJ	20.66	-66.4	13.41	-96.1	8.80	-104.9	3.01	-137.6	-3.30	-151.3	-5.41	-165.7	-2.22	29.7
14MAR89.AS	18.30	-131.6	11.06	-96.2	10.28	-82.9	9.20	-125.4	-1.64	-146.4	-5.96	-152.3	-2.12	-235.8
14MAR89.AT	18.41	-113.4	13.91	-105.7	11.26	-89.8	9.26	-141.6	-.70	-146.0	-5.37	-148.2	-2.71	-231.9
14MAR89.AU	21.35	-97.9	13.94	-76.1	12.24	-80.5	8.51	-138.9	-.26	-142.2	-4.64	-144.6	-2.95	-233.2
14MAR89.AV	17.15	-134.3	10.46	-76.6	8.88	-74.4	8.81	-121.5	-.12	-132.8	-5.71	-153.4	-4.38	-230.0
14MAR89.AW	16.42	-100.8	11.28	-77.1	10.08	-70.7	6.66	-120.9	.70	-135.8	-5.13	-146.5	-3.26	-232.1
14MAR89.AX	19.77	-87.7	9.94	-94.8	5.31	-88.5	5.31	-112.4	-.67	-134.2	-4.36	-143.0	-7.41	-269.9
14MAR89.AY	15.91	-98.3	10.62	-89.4	6.48	-75.7	8.42	-111.6	-.35	-135.8	-5.38	-146.9	-4.13	-267.1
14MAR89.AZ	16.78	-93.3	8.46	-79.6	5.27	-65.7	7.04	-98.0	-2.14	-129.6	-5.76	-151.8	-5.67	-261.4
14MAR89.BA	17.57	-81.8	6.67	-76.8	5.81	-72.3	7.52	-112.1	1.20	-140.1	-5.49	-135.1	-4.00	-254.4
14MAR89.BB	19.38	-124.9	13.96	-108.9	12.50	-98.1	8.66	-133.1	.70	-132.4	-5.46	-150.9	-8.42	-244.7
14MAR89.BC	18.93	-111.5	12.68	-109.8	9.84	-114.6	4.87	-123.3	-1.33	-144.7	-6.66	-152.4	-9.22	-252.0
14MAR89.BD	24.23	-89.0	12.63	-98.4	11.83	-108.2	6.19	-133.2	-2.29	-148.0	-6.24	-157.7	-6.35	-238.[illegible]
14MAR89.BE	23.77	-123.9	12.41	-84.9	8.97	-118.3	3.61	-140.8	-1.64	-154.5	-5.78	-177.4	-6.03	10.2
14MAR89.BF	16.32	-80.4	13.79	-103.1	7.19	-108.6	3.94	-138.2	-3.89	-151.7	-5.36	-167.8	-5.21	24.8
14MAR89.BG	17.55	-111.4	10.24	-74.4	6.68	-90.4	5.99	-134.1	-1.87	-132.3	-5.40	-143.1	-6.87	-249.7
14MAR89.BH	23.47	-114.1	13.01	-95.6	7.15	-101.0	6.04	-123.4	-1.80	-140.8	-6.41	-142.6	-6.29	-250.5
14MAR89.BI	18.47	-133.3	9.06	-89.9	6.68	-101.6	1.59	-119.6	-3.70	-138.6	-7.61	-140.8	-11.41	60.3
14MAR89.BJ	16.49	-51.4	10.79	-97.4	7.57	-100.6	3.43	-122.1	-3.57	-133.4	-5.36	-157.2	-7.57	81.4
14MAR89.BK	19.26	-126.0	11.79	-97.6	8.92	-97.6	4.61	-130.9	-3.90	-149.3	-9.46	-158.9	-7.78	-241.9
14MAR89.BL	19.18	-108.1	12.71	-99.1	8.48	-104.1	5.40	-129.1	-2.58	-141.5	-7.52	-153.1	-7.83	-259.1
14MAR89.BM	18.77	-120.8	9.81	-89.4	5.12	-91.9	3.09	-93.7	-2.26	-122.4	-6.56	-152.1	-8.96	61.5
14MAR89.BN	17.74	-84.0	9.30	-80.1	5.79	-99.8	3.15	-119.5	-2.24	-135.0	-6.93	-154.9	-11.12	76.2
14MAR89.BO	15.08	-76.4	11.09	-77.0	5.02	-94.0	2.47	-113.9	-2.95	-136.8	-4.82	-147.5	-9.99	85.2
14MAR89.BP	17.26	-49.2	12.83	-98.2	7.44	-95.2	5.47	-114.2	-2.27	-132.1	-5.74	-147.8	-10.36	85.8
14MAR89.CA	35.80	2.3	14.37	-73.5	9.31	-88.5	6.92	-113.7	-1.29	-153.7	-5.21	-150.1	-4.25	-233.5
14MAR89.CB	18.63	-89.9	13.02	-97.7	14.73	-86.0	8.83	-129.1	-.86	-146.3	-5.15	-156.6	-4.02	-236.1
14MAR89.CC	19.58	-113.4	9.44	-63.9	7.38	-78.6	5.52	-144.2	-2.04	-150.6	-5.28	-150.5	-4.17	-249.9
14MAR89.CD	15.76	-78.2	17.24	-88.4	9.41	-100.2	9.05	-121.3	-2.01	-146.1	-6.91	-155.3	-4.35	-245.5
14MAR89.CE	28.04	-109.7	11.32	-74.1	8.45	-85.5	7.08	-135.1	-2.74	-144.2	-5.16	-142.3	-6.95	-237.2
14MAR89.CF	20.58	-105.2	10.72	-101.8	9.64	-73.1	6.16	-120.8	1.05	-144.1	-6.03	-153.6	-3.45	-234.2
14MAR89.CG	17.84	-86.1	11.54	-87.3	8.71	-85.6	7.11	-120.8	-1.07	-138.4	-5.49	-152.4	-4.65	-243.3

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (ROLL)

RUN	0.30		0.40		0.70		1.80		3.00		4.00		7.00	
14MAR89.AK	14.24	-53.6	12.64	-57.8	7.42	-88.7	-1.30	-126.6	-5.04	-154.6	-7.22	-181.0	-11.21	-249.3
14MAR89.AL	19.92	-66.8	12.32	-71.4	9.80	-97.8	1.01	-121.5	-3.81	-157.6	-6.40	-173.9	-9.88	-249.2
14MAR89.AM	8.33	-45.1	14.24	-31.5	10.40	-85.1	-.59	-143.1	-7.21	-169.1	-9.06	-187.8	-12.93	-240.8
14MAR89.AN	12.77	-57.7	13.34	-49.4	12.39	-93.2	1.06	-141.7	-6.09	-170.3	-9.13	-201.6	-15.24	-259.4
14MAR89.AS	10.20	-68.3	10.31	-42.1	4.26	-87.6	-2.95	-121.6	-4.60	-160.4	-6.92	-179.5	-12.25	79.1
14MAR89.AT	7.56	-54.7	7.30	-81.6	6.08	-80.1	-1.69	-110.4	-3.64	-160.3	-5.02	-182.0	-9.49	-263.6
14MAR89.AU	10.11	-54.4	8.35	-72.8	5.60	-86.9	-1.78	-124.0	-4.12	-137.6	-5.88	-174.7	-8.68	77.3
14MAR89.AV	11.87	-24.3	17.46	15.3	6.66	-99.6	-1.54	-151.6	-12.52	-171.8	-12.31	-208.3	-15.29	78.1
14MAR89.AW	10.87	-67.6	9.61	-77.6	9.27	-62.4	-1.07	-145.7	-5.17	-192.7	-10.54	-222.3	-15.95	74.5
14MAR89.AX	13.90	-77.1	6.69	-70.0	6.11	-92.5	-1.54	-114.9	-4.50	-151.4	-8.07	-192.5	-12.02	78.4
14MAR89.AY	11.22	-78.9	9.21	-72.5	2.26	-96.1	-3.32	-128.2	-5.71	-153.5	-8.83	-198.5	-14.14	89.9
14MAR89.AZ	8.66	-4.3	15.70	24.3	4.70	-98.1	-2.93	-156.6	-6.90	-180.1	-11.54	-226.4	-18.35	65.6
14MAR89.BA	9.04	-26.6	6.34	-61.4	7.04	-61.1	-3.76	-155.3	-11.95	-218.0	-14.18	-223.3	-19.65	71.8
14MAR89.BQ	7.18	-56.9	10.41	-75.0	8.68	-96.3	-.72	-128.8	-4.74	-160.1	-6.03	-175.6	-8.44	-253.3
14MAR89.BR	14.74	-65.9	15.76	-95.7	8.90	-81.8	-.85	-129.1	-4.23	-152.6	-7.90	-164.5	-10.13	-241.9
14MAR89.BS	9.88	-31.8	15.11	4.1	8.02	-74.0	.50	-149.7	-5.77	-169.9	-9.50	-190.6	-13.97	-254.0
14MAR89.BT	11.69	-2.5	8.59	-48.7	8.46	-79.1	.76	-145.1	-5.91	-172.8	-9.83	-194.3	-13.67	-267.2
14MAR89.BU	10.91	-36.3	11.35	16.2	10.96	-73.1	1.48	-120.2	-3.67	-160.7	-6.87	-189.4	-14.50	-245.8
14MAR89.BV	9.88	-39.9	7.06	-9.4	3.59	-58.4	1.26	-123.2	-3.44	-150.4	-6.94	-195.7	-11.81	-250.0
14MAR89.BW	16.54	-93.8	13.25	-79.5	9.92	-91.2	.24	-123.5	-5.20	-147.0	-7.04	-168.7	-7.36	-239.2
14MAR89.BX	12.65	-91.0	20.44	-83.2	8.19	-100.3	-.15	-133.2	-3.89	-145.0	-7.30	-172.4	-9.42	-228.5
14MAR89.BY	8.30	-51.6	10.96	-4.7	8.04	-81.1	-.75	-144.1	-4.85	-172.7	-7.21	-193.4	-14.10	-248.9
14MAR89.BZ	10.23	-68.2	11.47	-56.0	6.10	-75.5	1.46	-134.0	-6.37	-163.8	-7.22	-195.1	-13.96	-252.5
14MAR89.CA	4.06	-37.7	10.37	-46.5	4.32	-65.1	-.98	-121.9	-4.97	-146.2	-5.69	-176.0	-9.01	76.1
14MAR89.CB	13.31	-64.6	14.36	-23.7	7.63	-83.8	-1.72	-130.2	-4.87	-151.3	-5.71	-182.4	-10.04	77.2
14MAR89.CC	4.95	-35.5	10.55	-72.6	6.10	-84.6	-2.95	-107.0	-5.22	-158.2	-6.34	-185.0	-10.75	-269.9
14MAR89.CD	10.19	-61.3	8.13	-56.2	3.02	-94.4	-.49	-123.5	-4.08	-140.5	-5.37	-189.3	-11.25	88.1
14MAR89.CE	9.10	-44.6	8.11	-56.7	6.25	-104.5	-3.52	-121.8	-5.73	-157.3	-7.96	-190.3	-11.81	71.6
14MAR89.CF	8.19	-38.5	7.15	-3.9	12.39	-105.0	-2.78	-143.3	-5.90	-184.0	-11.38	-207.5	-15.34	79.8
14MAR89.CG	12.50	-90.1	14.44	-44.0	9.63	-105.5	-2.06	-148.6	-8.56	-192.2	-11.91	-210.4	-18.29	65.8
14MAR89.CH	10.31	-38.8	3.43	-47.6	7.37	-65.4	-2.54	-114.9	-4.96	-147.6	-5.70	-173.0	-13.18	77.3
14MAR89.CI	10.45	-56.8	7.25	-34.7	5.96	-80.5	-2.84	-121.8	-6.22	-164.2	-8.06	-170.0	-9.62	86.2
14MAR89.CJ	7.47	-29.5	10.09	-86.3	3.55	-84.6	-3.10	-147.8	-5.92	-187.1	-12.18	-194.8	-19.71	78.1
14MAR89.CK	7.54	-36.3	3.62	-64.1	14.44	-81.2	-3.84	-146.7	-5.82	-179.1	-12.87	-179.3	-16.02	-262.5
14MAR89.CL	10.36	-55.2	11.47	-80.2	2.45	-77.2	-3.94	-106.8	-5.93	-156.0	-7.06	-173.3	-10.89	81.0
14MAR89.CM	8.92	-46.0	7.84	-77.1	2.85	-92.8	-5.17	-120.9	-10.09	-162.6	-9.38	-162.9	-14.17	72.5
14MAR89.CN	4.87	-40.2	7.33	-64.1	3.98	-82.4	-5.14	-117.6	-7.54	-152.2	-7.86	-174.7	-12.90	74.2

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (SPEED)

RUN	0.10		0.30		0.50		0.70	
14MAR89.AO	23.55	-71.1	16.68	-78.5	11.30	-86.2	10.64	-108.0
14MAR89.AP	29.68	-65.9	17.98	-93.1	13.07	-98.4	11.45	-100.7
14MAR89.AQ	37.38	-89.2	22.78	-129.6	16.35	-129.1	11.37	-121.5
14MAR89.AR	32.86	-155.3	20.83	-144.0	12.77	-142.8	9.90	-149.8
14MAR89.BB	12.89	-77.8	4.40	-70.9	1.32	-78.4	-4.44	-90.1
14MAR89.BC	12.86	-83.8	3.23	-80.4	.59	-98.8	.28	-117.8
14MAR89.BD	11.91	-65.1	8.55	-73.0	-.13	-29.1	1.63	-97.2
14MAR89.BE	11.10	-77.8	5.46	-80.0	-.58	-38.7	.93	-90.8
14MAR89.BF	10.92	-67.9	5.97	-67.5	-4.75	-57.3	-1.25	18.0
14MAR89.BG	28.01	-109.7	10.88	-145.2	9.25	-126.9	1.82	-164.0
14MAR89.BH	28.31	-117.2	12.67	-160.5	7.44	-154.1	3.30	-150.5
14MAR89.BI	14.48	-63.0	6.91	-85.2	-.74	-50.5	-4.74	-108.3
14MAR89.BJ	17.00	-73.7	7.55	-73.2	-.61	-90.4	3 [illegible]	-100.8
14MAR89.BK	30.59	-97.4	18.64	-123.2	12.48	-144.3	6.53	-154.7
14MAR89.BL	26.72	-86.5	15.04	-130.6	7.53	-140.6	2.45	-148.5
14MAR89.BM	22.71	-55.7	14.57	-147.4	8.14	-147.6	3.22	-154.1
14MAR89.BN	26.55	-94.3	14.53	-111.0	12.99	-135.2	.95	-145.8
14MAR89.BO	37.10	-76.5	19.30	-135.9	10.46	-154.1	4.43	-161.6
14MAR89.BP	29.49	-113.3	15.94	-163.1	10.28	-165.0	4.06	-148.1
14MAR89.BQ	31.09	-71.9	17.41	-102.2	10.20	-149.4	9.45	-158.3
14MAR89.BR	30.17	-88.9	15.38	-120.6	9.78	-116.6	2.11	-97.6
14MAR89.BS	15.11	-66.9	9.08	-83.2	.54	-71.3	4.11	-90.8
14MAR89.BT	14.74	-64.6	9.82	-65.9	3.66	-85.0	3.80	-106.4
14MAR89.BU	37.07	-97.3	21.60	-170.2	13.46	-158.3	8.45	-172.9
14MAR89.BV	44.24	75.0	20.54	-142.7	11.36	-143.5	10.40	-162.1
14MAR89.BW	16.46	-58.2	9.46	-78.9	3.40	-71.7	4.24	-90.9
14MAR89.BX	18.93	-70.0	9.89	-67.8	5.43	-59.7	2.17	-94.1
14MAR89.BY	34.90	-93.6	18.96	-104.6	19.48	-152.1	7.04	-130.9
14MAR89.BZ	25.03	-104.9	18.93	-145.7	15.32	-135.3	8.36	-144.0
14MAR89.CA	13.42	-64.1	7.3[illegible]	-45.2	.81	-82.4	2.21	-128.8
14MAR89.CB	14.86	-68.6	5.44	-73.7	3.78	-92.4	-2.64	-95.8
14MAR89.CC	15.33	-76.6	9.29	-90.7	5.40	-105.1	8.99	-118.6
14MAR89.CD	19.92	-183.8	16.64	-269.1	5.05	-157.3	3.41	-175.4
14MAR89.CE	24.28	-103.9	13.36	-125.1	5.68	-162.8	1.28	-132.6
14MAR89.CF	10.98	-63.6	4.98	-61.9	-.89	-61.9	1.21	-92.9
14MAR89.CG	14.46	-69.3	5.70	-69.1	1.90	-97.0	2.58	-46.8
14MAR89.CH	13.83	-66.1	4.11	-87.3	3.45	-98.1	1.48	-103.4

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (PITCH)

RUN	0.20		0.50		0.90		1.40		2.40		4.20		9.00	
15MAR89.AA	22.03	-66.4	12.85	-109.7	6.84	-107.9	2.97	-109.6	-1.84	-121.3	-4.16	-144.2	-5.99	-237.7
15MAR89.AB	20.71	-96.8	13.82	-99.7	8.69	-111.2	4.67	-114.1	.46	-126.5	-4.07	-151.1	-5.69	-211.3
15MAR89.AC	23.13	-85.0	11.55	-94.8	5.53	-100.7	2.60	-108.0	-.51	-109.0	-2.18	-143.6	-5.45	-247.1
15MAR89.AD	23.27	-92.2	12.87	-93.5	6.54	-99.8	4.43	-97.2	.99	-122.5	-1.30	-142.1	-2.81	-243.8
15MAR89.AE	20.97	-116.1	9.58	-94.2	2.65	-108.4	.04	-110.2	-1.41	-128.5	-3.51	-165.6	-4.25	39.1
15MAR89.AF	16.12	-95.4	7.65	-100.8	3.55	-98.9	.24	-103.5	-.39	-130.3	-3.13	-159.6	-3.53	42.8
15MAR89.AG	16.10	-83.6	8.73	-102.9	3.23	-100.8	.96	-106.1	-2.57	-121.1	-3.71	-160.3	-.47	53.4
15MAR89.AH	12.74	-86.1	2.41	-102.5	-3.77	-104.4	-4.82	-101.5	-6.28	-119.4	-6.39	-155.2	-11.48	-10.0
15MAR89.AI	6.97	-106.8	2.15	-94.3	-2.53	-97.4	-4.38	-101.7	-8.00	-115.4	-7.30	-150.5	-7.64	-5.4
15MAR89.AP	15.76	-113.1	9.72	-104.6	3.93	-105.3	.02	-104.6	-2.67	-126.2	-8.57	-150.2	-4.86	81.4
15MAR89.AQ	16.80	-111.0	9.87	-90.1	4.01	-101.7	2.02	-116.6	-4.37	-132.4	-5.41	-145.6	-1.47	75.7
15MAR89.AR	24.16	-30.8	8.59	-95.7	3.66	-94.6	.74	-105.9	-4.14	-124.5	-5.19	-146.9	-1.64	-256.8
15MAR89.AS	12.92	-54.0	6.79	-80.3	3.13	-98.2	-.06	-95.3	-3.35	-120.2	-5.02	-136.0	-1.19	-265.6
15MAR89.AT	12.32	-99.2	6.23	-101.9	.97	-107.1	-1.47	-119.5	-6.23	-137.5	-5.63	-172.0	-3.37	-3.9
15MAR89.AU	15.42	-76.1	8.25	-88.7	2.31	-106.3	-1.22	-110.7	-5.42	-129.0	-5.71	-163.7	-.67	-11.3
15MAR89.AV	12.12	-96.4	1.24	-105.3	-3.64	-105.2	-7.04	-110.4	-9.03	-123.0	-6.91	-153.6	-10.11	-56.8
15MAR89.AW	11.15	-77.1	2.74	-103.1	-2.34	-103.1	-6.03	-100.7	-6.57	-101.2	-6.92	-157.7	-6.74	-52.5
15MAR89.AX	12.24	-86.3	7.00	-95.4	1.25	-105.8	-1.98	-120.7	-5.64	-147.0	-6.50	-168.3	-2.86	-15.3
15MAR89.AY	15.11	-86.7	7.34	-90.8	1.91	-106.7	-1.08	-114.7	-4.17	-140.4	-5.65	-164.7	-.78	-9.4
15MAR89.AZ	16.25	-124.2	8.37	-99.3	4.97	-104.2	1.11	-121.2	-2.76	-145.7	-5.42	-171.3	-.25	-25.7
15MAR89.BA	18.78	-101.2	9.07	-92.4	4.17	-103.0	1.14	-124.6	-3.76	-138.1	-5.85	-168.5	1.04	-28.1
15MAR89.BB	16.08	-101.0	11.41	-90.5	4.75	-102.6	2.00	-108.4	-.96	-133.7	-5.62	-155.6	-3.76	75.6
15MAR89.BC	18.62	-106.5	8.85	-83.6	5.59	-97.0	2.32	-111.2	-1.21	-128.5	-4.41	-149.3	-4.32	72.9
15MAR89.BD	8.74	-29.3	7.10	-57.8	3.84	-70.7	4.92	-77.7	-2.98	-115.3	-5.82	-151.5	-4.47	-246.2
15MAR89.BE	10.67	-36.3	5.85	-53.9	4.70	-63.6	2.39	-91.3	-.99	-106.1	-5.65	-151.7	-3.50	-264.0
15MAR89.BF	6.42	-28.8	6.03	-51.1	3.48	-64.8	1.46	-90.8	-1.42	-130.0	-5.03	-151.2	-2.83	54.0
15MAR89.BG	8.11	-33.7	4.02	-64.3	3.67	-71.2	3.03	-89.8	-1.75	-123.8	-5.43	-155.9	-3.80	16.2
15MAR89.BH	10.73	-83.6	4.90	-94.0	.85	-94.7	-1.27	-100.9	-5.58	-119.0	-7.77	-146.8	-4.56	68.3
15MAR89.BI	8.65	-105.0	6.04	-79.3	2.74	-83.8	-1.60	-106.0	-2.17	-116.8	-5.87	-147.1	-4.18	66.9
15MAR89.BJ	13.09	-86.1	2.50	-96.9	-2.43	-105.1	-5.42	-112.0	-6.92	-117.4	-6.76	-166.8	-11.69	-70.4
15MAR89.BK	9.92	-97.5	.80	-102.1	-3.22	-109.0	-7.02	-109.1	-6.48	-132.2	-7.80	-158.6	-14.19	-67.8

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (ROLL)

RUN	0.30		0.40		0.70		1.80		3.00		4.00		7.00	
15MAR89.AJ	15.85	-115.6	12.01	-74.2	9.71	-116.2	.20	-132.4	-2.50	-149.2	-4.73	-174.1	-4.93	-252.8
15MAR89.AK	16.68	-76.4	17.71	-103.6	10.18	-112.8	1.09	-135.4	-2.80	-147.4	-4.89	-163.5	-5.77	-248.5
15MAR89.AL	24.20	-5.2	15.44	-87.5	13.77	-99.6	-.15	-151.5	-4.15	-177.6	-4.94	-204.4	-9.91	81.9
15MAR89.AM	21.05	-66.9	16.69	-134.6	9.04	-108.2	.56	-152.3	-5.19	-175.0	-6.92	-198.5	-8.53	58.0
15MAR89.AN	8.68	-87.4	11.95	-125.4	7.85	-129.8	-4.11	-170.4	-7.20	-230.5	-12.85	-235.6	-17.61	30.7
15MAR89.AO	12.31	-74.3	13.91	-93.3	5.55	-123.7	-2.88	-159.4	-5.33	-202.9	-9.78	-244.3	-13.24	-6.9
15MAR89.AP	12.49	-98.8	15.29	-144.3	6.66	-82.8	-2.24	-118.5	-4.88	-146.5	-8.53	-170.4	-11.20	59.0
15MAR89.AQ	15.54	-122.5	11.00	-73.2	4.16	-106.1	-4.69	-136.2	-3.30	-125.3	-3.39	-177.0	-9.74	71.0
15MAR89.AR	11.52	-179.7	5.55	12.8	8.14	-136.1	-.56	-155.3	-11.84	-179.2	-5.64	-209.8	-10.25	23.8
15MAR89.AS	18.20	-13.1	16.18	-8.9	9.25	-165.6	.05	-154.3	-3.05	-181.1	-8.46	-220.9	-6.16	.2
15MAR89.AT	9.83	-110.6	16.34	-131.5	7.06	-94.5	-4.48	-106.8	-8.14	-163.2	-4.77	-185.9	-8.86	22.0
15MAR89.AU	1.65	-76.1	9.12	-57.2	2.37	-123.9	-9.45	-97.8	-5.39	-154.1	-15.07	-259.9	-12.77	-4.1
15MAR89.AV	11.63	-41.0	.74	-89.7	-.57	-97.2	-11.17	-139.6	-9.50	-175.8	-10.02	-222.5	-23.04	47.2
15MAR89.AW	12.07	-66.3	6.32	-132.3	2.23	-84.7	-5.99	-154.3	-8.49	-204.4	-8.59	-223.3	-16.47	33.1
15MAR89.AX	10.48	-116.8	18.25	-126.5	3.03	-114.9	-4.49	-160.1	-10.20	-204.7	-9.37	-240.9	-21.43	25.0
15MAR89.AY	-.10	-12.3	23.38	-122.1	7.98	-131.4	-5.41	-165.6	-7.33	-203.5	-18.04	-214.0	-21.61	28.5
15MAR89.AZ	8.07	-102.0	22.96	59.0	2.95	-109.5	-9.30	-103.5	-4.67	-151.3	-3.88	-175.7	-9.33	21.7
15MAR89.BA	11.01	-119.4	16.27	-90.3	1.43	-66.5	-5.42	-127.6	-7.08	-155.6	-6.49	-184.5	-14.79	10.0
15MAR89.BH	11.39	14.7	6.39	-128.1	4.34	-60.3	-4.46	-169.8	-8.05	88.6	-11.13	-265.3	-22.16	-64.3
15MAR89.BI	6.00	1.8	5.40	-134.1	8.01	-123.4	-6.13	-171.7	-8.95	-207.1	-20.01	-214.9	-17.69	-47.8
15MAR89.BJ	3.47	-23.8	4.40	-86.2	3.48	-132.1	-7.89	-194.4	-12.45	-233.7	-20.48	78.9	-30.07	-26.5
15MAR89.BK	3.14	34.3	3.20	-17.9	1.67	-113.5	-9.51	-187.5	-15.04	-219.1	-15.74	-257.0	-24.48	-23.1

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (PITCH)

RUN	0.20		0.50		0.90		1.40		2.40		4.20		9.00	
16MAR89.AA	23.84	-107.0	17.40	-108.1	8.90	-113.3	5.39	-120.7	-.45	-142.8	-4.89	-159.4	-7.84	-231.7
16MAR89.AB	22.49	-77.1	14.47	-97.1	8.71	-105.0	4.96	-120.0	.57	-140.9	-4.97	-157.1	-6.04	-254.9
16MAR89.AC	18.65	-109.5	10.15	-101.6	5.20	-102.4	-.07	-113.2	-1.97	-135.5	-4.35	-170.6	-3.33	36.3
16MAR89.AD	17.93	-84.7	8.33	-100.3	4.09	-102.4	1.11	-114.1	-1.57	-137.2	-4.85	-166.0	-3.98	21.2
16MAR89.AE	13.39	-99.0	4.30	-93.4	-.46	-100.6	-3.03	-107.0	-4.33	-105.9	-6.37	-141.7	-15.69	59.0
16MAR89.AF	14.90	-88.9	7.50	-93.2	2.13	-94.0	-.23	-98.3	-2.90	-110.9	-5.09	-145.4	-10.93	56.9
16MAR89.AO	17.69	-95.1	13.83	-120.1	7.23	-114.8	2.23	-127.2	-3.35	-144.3	-7.65	-154.3	-8.34	-238.5
16MAR89.AP	20.01	-100.7	13.86	-88.6	6.93	-114.1	1.60	-126.5	-3.54	-139.6	-8.91	-154.6	-6.51	-239.4
16MAR89.AQ	13.11	-89.2	7.92	-90.6	2.68	-104.3	-.16	-122.8	-4.12	-133.8	-4.81	-175.1	-1.74	-4.7
16MAR89.AR	12.85	-88.3	6.35	-91.0	1.57	-106.8	-1.36	-118.8	-6.08	-130.0	-5.28	-167.0	-3.23	-1.6
16MAR89.AS	13.79	-96.9	6.02	-91.2	.06	-94.7	-3.01	-94.8	-3.24	-115.2	-5.58	-139.9	-7.00	34.2
16MAR89.AT	14.23	-84.7	4.41	-90.2	.74	-91.1	-2.57	-85.5	-.90	-108.5	-5.16	-139.1	-4.95	51.3
16MAR89.AU	10.91	-90.3	4.33	-88.6	-.94	-98.7	-6.76	-90.7	-4.60	-117.3	-5.55	-144.1	-9.33	37.6
16MAR89.AV	11.90	-85.1	3.82	-85.9	-1.01	-88.7	-5.29	-90.4	-3.83	-116.5	-5.37	-136.5	-10.70	56.9
16MAR89.AW	21.59	-101.4	11.39	-96.1	6.28	-98.5	4.08	-120.7	-1.58	-134.5	-6.40	-168.9	-7.36	86.9
16MAR89.AX	16.95	-80.4	11.01	-77.7	6.77	-90.3	3.13	-110.1	-.56	-128.4	-4.60	-154.2	-4.03	84.1
16MAR89.AY	22.85	-71.8	13.35	-105.3	7.23	-102.9	3.60	-109.4	-1.93	-130.0	-5.26	-145.7	-4.19	-224.1
16MAR89.AZ	17.92	-117.9	9.66	-92.3	4.76	-106.1	1.56	-106.1	-4.43	-125.3	-6.47	-143.5	-5.55	-243.1
16MAR89.BA	16.15	-74.5	8.73	-80.6	5.05	-117.3	1.90	-132.2	-4.59	-165.4	-1[illegible].57	-213.2	-20.14	37.1
16MAR89.BB	16.20	-127.8	11.91	-102.4	4.84	-110.5	1.97	-127.4	-2.74	-161.2	-9.59	-213.5	-16.68	45.6
16MAR89.BC	14.17	-80.1	4.07	-68.3	2.39	-82.5	2.04	-88.7	-.98	-127.4	-5.74	-153.0	-6.44	64.9
16MAR89.BD	11.63	-74.7	6.09	-72.0	4.41	-83.5	2.46	-90.2	-1.41	-136.1	-6.31	-156.8	-5.11	86.6
16MAR89.BI	15.32	-81.4	7.31	-92.5	3.76	-112.1	-.28	-137.6	-6.18	-167.1	-11.77	-210.6	-18.58	32.9
16MAR89.BJ	14.22	-71.9	9.74	-74.7	4.84	-109.3	.95	-133.6	-5.17	-159.3	-9.66	-202.0	-14.33	41.6
16MAR89.BK	14.64	-68.5	7.57	-80.9	2.85	-98.7	1.67	-94.0	-3.07	-106.4	-5.14	-138.4	-2.05	-238.3
16MAR89.BL	18.85	-71.5	9.45	-86.9	3.71	-97.6	2.47	-102.3	-1.83	-101.8	-4.87	-138.2	-1.93	-232.6
16MAR89.BM	26.80	-100.0	8.19	-92.7	2.30	-100.3	.46	-103.5	-4.70	-130.8	-5.98	-156.2	-5.02	67.5
16MAR89.BN	14.73	-100.4	6.71	-90.4	2.35	-95.6	-.20	-96.6	-2.65	-133.3	-5.53	-155.1	-4.85	69.9
16MAR89.BO	12.33	-73.1	7.52	-72.6	3.85	-69.7	2.78	-96.5	.26	-124.2	-4.53	-150.9	-2.29	-258.4
16MAR89.BP	10.16	-84.4	5.98	-64.7	3.31	-71.5	3.13	-77.9	-.01	-125.1	-4.20	-146.8	-1.26	-266.6

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (ROLL)

RUN	0.30		0.40		0.70		1.80		3.00		4.00		7.00	
16MAR89.AG	15.79	-83.0	14.77	-72.1	12.56	-107.3	2.63	-125.4	-2.32	-148.3	-2.89	-166.8	-4.85	-250.3
16MAR89.AH	17.57	-18.1	15.89	-68.1	9.28	-81.4	.44	-122.8	-.83	-133.6	-3.00	-164.5	-3.28	-245.4
16MAR89.AI	11.74	-77.0	14.09	-95.7	9.80	-110.8	.33	-141.0	-2.68	-172.4	-5.00	-204.5	-9.15	48.9
16MAR89.AJ	13.15	-104.9	15.28	-78.9	7.18	-111.9	-.58	-131.7	-4.03	-174.9	-4.41	-197.3	-8.22	41.1
16MAR89.AK	15.74	-122.3	6.92	-97.6	9.61	-121.8	-2.06	-162.0	-6.63	-209.2	-9.97	-241.5	-17.22	26.3
16MAR89.AL	9.72	-109.2	13.29	-123.8	11.22	-112.2	-.82	-156.2	-4.63	-209.2	-7.90	-237.2	-14.71	13.0
16MAR89.AM	15.09	-75.9	9.43	-86.0	4.95	-96.1	-1.61	-127.4	-6.93	-153.1	-8.79	-178.5	-13.40	-269.4
16MAR89.AN	10.94	-73.5	12.11	-120.5	6.71	-106.5	-1.58	-136.0	-4.63	-162.4	-7.69	-184.5	-11.11	-253.1
16MAR89.AO	10.48	-37.7	12.03	-106.1	2.19	-100.9	-3.65	-130.3	-4.80	-152.8	-6.24	-196.4	-9.53	75.5
16MAR89.AP	25.34	-43.1	11.30	-81.7	5.52	-97.2	-1.79	-138.4	-4.17	-161.7	-7.67	-168.9	-9.30	59.6
16MAR89.AQ	11.89	-101.0	7.12	-85.9	2.34	-144.4	-10.77	-184.1	-15.04	-227.8	-22.76	72.1	-26.11	-5.4
16MAR89.AR	4.10	-85.0	3.15	-78.8	-1.93	-137.8	-13.02	-188.8	-21.69	-232.9	-21.26	-257.1	-25.61	-23.8
16MAR89.AS	11.04	-61.8	12.20	-73.4	6.49	-121.0	-5.40	-149.7	-6.50	-180.1	-7.68	-208.6	-13.56	63.6
16MAR89.AT	12.12	-68.9	9.88	-82.9	7.39	-108.6	-2.10	-137.6	-12.10	-150.2	-8.33	-168.1	-14.07	40.6
16MAR89.AU	4.59	-28.2	5.32	-128.7	2.96	-145.7	-7.38	-207.3	-34.26	-102.7	-16.81	-269.0	-29.95	-59.3
16MAR89.AV	10.59	-119.7	11.17	-115.1	10.01	-150.2	-6.55	-218.4	-30.16	-127.7	-11.49	88.3	-16.96	-33.7
16MAR89.BE	16.84	-104.4	12.86	-68.1	5.84	-100.9	-.03	-127.1	-4.56	-154.9	-5.70	-174.2	-9.56	-265.3
16MAR89.BF	17.27	-53.7	11.35	-46.3	9.39	-104.8	-.31	-130.8	-7.35	-154.9	-6.14	-178.5	-7.44	88.4
16MAR89.BG	8.25	-86.5	15.05	-92.3	3.63	-93.8	-1.81	-132.7	-4.50	-176.7	-3.56	-213.9	-9.18	14.4
16MAR89.BH	9.46	-79.5	9.72	-90.7	2.93	-110.5	-3.47	-130.0	-5.70	-175.6	-4.10	-193.9	-9.04	18.7
16MAR89.BI	8.43	-58.8	10.20	-54.5	-.01	-79.1	-5.05	-125.2	-10.59	-148.3	-8.00	-181.8	-8.47	51.0
16MAR89.BJ	8.72	-127.4	15.88	-92.5	1.83	-93.7	-7.49	-100.5	-7.90	-148.8	-7.35	-173.6	-9.63	42.1
16MAR89.BK	5.25	-72.8	13.16	-53.7	9.31	-105.3	-4.01	-146.1	-7.11	-158.3	-5.96	-192.2	-14.02	42.2
16MAR89.BL	6.66	-38.5	4.84	-64.6	7.11	-85.2	-1.62	-137.6	-6.54	-158.3	-6.27	-188.2	-11.78	74.8
16MAR89.BM	7.64	-90.6	9.59	-94.8	9.11	-111.8	-3.23	-127.5	-4.11	-166.1	-3.66	-200.7	-12.73	2.8
16MAR89.BN	11.59	-82.0	13.24	-85.9	3.35	-109.2	-4.58	-137.2	-5.70	-189.6	-6.08	-223.8	-11.02	-19.9
16MAR89.BO	8.10	-79.1	19.80	-154.0	7.86	-93.4	-3.08	-133.1	-6.59	-155.1	-7.23	-197.4	-8.65	56.5
16MAR89.BP	11.81	-38.4	15.80	-97.6	7.91	-91.1	-2.83	-131.9	-8.03	-152.7	-5.38	-173.5	-10.14	50.7

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (PITCH)

RUN	0.20		0.50		0.90		1.40		2.40		4.20		9.00	
16MAR89.BQ	17.85	-67.2	11.97	-75.0	7.61	-93.5	4.65	-117.0	-1.42	-133.3	-3.85	-154.8	-9.82	-252.2
16MAR89.BR	19.83	-74.7	15.95	-88.8	9.91	-92.4	6.39	-117.9	-.05	-132.1	-3.64	-156.9	-4.80	-239.8
16MAR89.BS	11.68	-74.5	8.53	-91.7	5.83	-104.5	1.79	-118.5	-.44	-138.0	-3.33	-179.4	-2.97	-13.8
16MAR89.BT	10.19	-87.2	7.86	-86.0	3.19	-97.4	.67	-112.7	-2.64	-132.3	-3.81	-185.4	-3.19	-14.9
16MAR89.BU	18.92	-18.6	1.17	-101.6	-2.42	-94.1	-3.16	-107.4	-6.04	-114.4	-3.80	-161.9	-8.75	-29.5
16MAR89.BV	8.97	-92.8	2.53	-88.4	-2.16	-100.2	-3.86	-100.8	-4.66	-129.6	-3.25	-174.7	-9.55	-39.1
16MAR89.CE	20.75	-103.9	14.84	-110.6	8.07	-116.0	4.02	-125.8	-1.12	-143.0	-5.32	-160.8	-6.84	-223.1
16MAR89.CF	21.42	-52.6	12.79	-109.5	9.26	-113.5	4.69	-126.9	-.46	-144.8	-5.02	-160.1	-5.47	-227.5
16MAR89.CG	12.89	-85.8	7.36	-102.4	3.46	-101.8	.18	-113.5	-2.32	-142.3	-3.77	-185.7	-5.12	-.2
16MAR89.CH	15.54	-69.2	7.44	-97.7	2.43	-93.6	.43	-111.1	-1.64	-138.2	-3.93	-182.6	-3.72	6.1
16MAR89.CI	10.84	-104.5	.16	-93.9	-3.36	-91.3	-4.23	-103.7	-8.04	-117.5	-2.67	-170.9	-7.59	-39.5
16MAR89.CJ	10.09	-103.0	2.03	-85.1	-2.03	-101.4	-3.43	-95.7	-1.92	-97.1	-9.75	-162.0	-8.92	-48.6
16MAR89.CM	23.64	-103.9	11.32	-95.0	6.63	-91.4	4.14	-99.5	2.42	-121.1	-2.31	-154.1	-3.11	80.2
16MAR89.CN	17.44	-129.1	8.10	-81.7	7.32	-94.9	2.97	-98.8	-2.24	-112.2	-2.01	-150.2	-.76	84.9

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (ROLL)

RUN	0.30		0.40		0.70		1.80		3.00		4.00		7.00	
16MAR89.BW	16.65	-95.8	13.54	-97.4	7.41	-110.7	-1.43	-120.2	-4.50	-122.4	-5.09	-150.7	-7.49	-223.0
16MAR89.BX	9.85	-112.1	12.09	-86.3	5.46	-97.1	-2.38	-131.5	-3.86	-137.7	-7.25	-168.3	-7.17	-225.6
16MAR89.BY	17.48	-111.7	10.30	-88.3	6.21	-113.3	-.70	-132.3	-3.67	-160.3	-6.02	-193.1	-8.51	74.7
16MAR89.BZ	14.61	-73.3	9.04	-91.4	6.14	-110.7	-1.98	-117.5	-4.68	-166.0	-7.11	-189.2	-9.29	66.9
16MAR89.CA	19.27	-65.8	10.44	-109.7	7.89	-114.1	-5.31	-185.5	-8.43	-248.0	-11.31	-249.5	-20.56	-24.4
16MAR89.CB	11.50	-109.1	10.78	-106.9	5.59	-120.5	-3.57	-182.0	-13.84	-199.5	-8.26	86.1	-13.00	-29.9
16MAR89.CC	17.80	-89.6	12.83	-92.3	5.46	-144.0	-4.17	-179.9	-6.73	-216.3	-2.33	62.5	-17.42	-109.9
16MAR89.CD	19.81	-165.2	12.33	-144.4	10.99	-151.5	-1.90	-160.3	-2.90	-212.0	-12.36	-171.9	-20.07	-241.6
16MAR89.CE	11.14	-103.6	13.75	-143.0	7.76	-102.0	-4.10	-109.5	-4.78	-149.4	-6.32	-177.3	-6.25	-244.2
16MAR89.CF	13.05	-84.7	10.98	-108.7	5.66	-118.5	-2.79	-122.6	-2.32	-145.6	-4.80	-158.1	-2.68	-242.5
16MAR89.CG	8.25	-168.7	9.58	-118.9	6.96	-84.6	-2.40	-153.3	-3.72	-195.7	-4.30	-184.2	-5.74	46.4
16MAR89.CH	15.23	-221.0	9.28	-102.0	6.09	-119.2	-.23	-153.2	-4.72	-168.2	-5.84	-238.1	-9.35	65.0
16MAR89.CI	9.41	-75.6	4.68	-136.7	7.13	-98.9	-4.54	-220.7	-9.81	-269.5	-14.59	81.4	-19.89	-49.2
16MAR89.CJ	6.98	-122.7	13.25	-88.8	5.35	-155.0	-15.08	-172.3	-16.66	86.9	-17.30	72.2	-24.43	-61.2
16MAR89.CM	14.96	-138.0	8.02	-97.9	10.20	[illegible]	-.46	-132.5	-2.21	-153.5	-4.60	-188.5	-5.74	57.0
16MAR89.CN	8.40	-117.2	22.97	-45.9	10.01	-129.5	.98	-120.7	-5.61	-186.6	-3.86	-183.3	-3.78	63.3

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (PITCH)

RUN	0.20		0.50		0.90		1.40		2.40		4.20		9.00	
20MAR89.AA	21.02	-88.0	15.92	-109.3	10.94	-110.3	6.45	-120.4	.69	-129.1	-3.43	-152.3	-5.29	-246.6
20MAR89.AB	22.14	-109.0	14.10	-90.2	10.24	-107.3	6.27	-127.0	.90	-139.9	-2.59	-149.7	-5.66	-245.8
20MAR89.AC	29.22	-139.5	12.93	-96.7	7.67	-121.1	4.53	-133.2	-2.00	-151.2	-3.01	-165.6	-2.07	25.7
20MAR89.AD	23.31	-107.4	12.47	-86.2	8.48	-111.8	4.01	-133.8	-1.59	-146.5	-3.23	-167.3	-1.02	21.2
20MAR89.AE	26.37	-93.8	19.53	-121.8	11.61	-126.5	6.15	-147.0	-.63	-144.1	-6.01	-156.5	-6.64	-212.9
20MAR89.AF	24.44	-107.4	19.44	-102.0	13.61	-123.9	7.90	-141.9	1.02	-144.4	-4.14	-148.0	-5.27	-214.8
20MAR89.AG	16.97	-102.0	10.13	-104.7	6.58	-103.5	2.23	-119.6	-3.47	-133.2	-4.98	-133.9	-9.96	50.1
20MAR89.AH	18.15	-111.0	10.62	-92.5	7.91	-79.2	4.26	-115.3	-1.62	-139.1	-4.68	-149.2	-5.09	74.1
20MAR89.AI	23.95	-115.8	12.87	-75.5	10.72	-82.0	9.72	-120.6	1.65	-144.1	-3.03	-149.4	-2.66	-232.9
20MAR89.AJ	17.80	-99.0	11.59	-69.3	10.14	-79.8	11.45	-122.3	2.46	-134.8	-2.51	-148.4	-3.04	-231.0
20MAR89.AK	16.91	-101.4	7.93	-99.0	5.08	-114.5	1.13	-139.9	-4.37	-145.5	-7.09	-167.3	-11.30	-19.7
20MAR89.AL	12.97	-85.8	10.06	-108.8	6.15	-107.5	3.78	-138.2	-2.87	-151.4	-6.04	-171.6	-6.25	-30.9
20MAR89.AM	23.09	-73.6	10.54	-79.1	6.43	-95.3	4.25	-140.1	-3.65	-153.3	-5.35	-167.8	-8.14	-60.8
20MAR89.BA	21.38	-111.7	12.81	-98.8	5.00	-111.9	-.02	-123.7	-4.76	-113.2	-6.21	-141.7	-6.73	-247.5
20MAR89.BB	18.51	-111.8	10.92	-89.4	5.06	-107.9	.50	-116.0	-5.60	-139.5	-6.98	-139.4	-6.98	-253.7
20MAR89.BC	14.27	-77.5	9.75	-107.3	2.35	-116.3	-.39	-116.6	-4.77	-126.5	-7.64	-145.5	-7.80	-252.8
20MAR89.BD	20.52	-153.9	8.45	-109.1	3.41	-111.3	.02	-109.6	-5.41	-119.5	-3.50	-129.7	-8.51	69.3
20MAR89.BE	13.19	-66.5	7.87	-93.1	3.57	-107.8	-.08	-117.3	-5.53	-92.4	-5.09	-131.0	-6.47	68.5
20MAR89.BF	22.61	-100.4	11.44	-100.9	4.89	-120.0	.22	-140.3	-4.33	-149.7	-5.93	-169.3	-4.86	8.4
20MAR89.BG	13.22	-104.8	12.86	-78.9	5.31	-118.9	1.45	-129.2	-4.01	-144.4	-4.50	-167.2	-2.55	1.9
20MAR89.BH	9.74	-93.3	6.07	-96.5	-2.19	-80.8	-1.52	-106.4	-4.56	-80.8	-2.90	-123.0	-6.99	80.8
20MAR89.BI	38.70	24.8	8.66	-115.9	.98	-97.1	-3.03	-101.3	-4.69	-125.0	-6.19	-99.5	-4.84	70.1
20MAR89.BJ	8.90	-100.2	6.79	-108.5	1.22	-107.0	1.60	-106.8	-7.42	-103.2	-6.14	-141.6	-7.04	73.3

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (ROLL)

RUN	0.30		0.40		0.70		1.80		3.00		4.00		7.00	
20MAR89.AN	24.09	-96.0	14.98	-97.9	12.36	-120.2	.81	-143.0	-3.66	-159.6	-3.26	-188.9	-10.68	-252.0
20MAR89.AO	26.02	-171.1	20.77	-82.6	12.41	-121.7	.25	-136.5	-1.33	-165.8	-3.53	-183.6	-7.22	-251.9
20MAR89.AP	19.94	-104.4	18.84	-142.8	10.50	-110.8	.23	-141.0	-2.54	-172.0	-2.81	-191.1	-8.93	74.1
20MAR89.AQ	23.21	-36.3	15.72	-50.5	10.13	-121.2	.83	-145.5	-2.95	-173.7	-4.66	-211.7	-8.48	64.3
20MAR89.AR	8.27	-53.6	10.97	-99.9	10.76	-138.8	-.15	-161.0	-4.39	-209.2	-11.78	-243.3	-17.59	33.0
20MAR89.AS	9.88	-36.8	14.54	-39.3	8.66	-138.3	-.73	-161.0	-11.20	-173.5	-12.97	-238.5	-15.97	24.2
20MAR89.AT	17.28	-66.2	23.25	-72.2	10.06	-133.3	.76	-160.8	-3.94	-193.0	-9.50	-233.3	-17.86	73.0
20MAR89.AU	13.63	-131.2	8.87	-67.9	11.40	-147.2	1.97	-164.8	-4.07	-193.3	-8.98	-240.8	-16.91	66.3
20MAR89.AV	16.51	-38.4	7.74	-50.6	9.28	-111.7	.84	-156.9	-1.63	-202.4	-8.37	-223.6	-20.25	56.1
20MAR89.AW	14.78	-115.2	17.96	11.3	5.94	-137.1	-.57	-167.2	3.62	-265.5	-2.30	-268.6	-15.10	-14.4
20MAR89.AX	13.96	-19.6	5.18	-99.7	2.66	-99.3	-.63	-146.2	-3.73	-144.3	-5.01	-204.3	-10.93	36.6
20MAR89.AY	8.90	-76.8	10.97	-106.5	10.45	-102.8	1.32	-157.5	-3.42	-216.7	-5.56	-257.4	-12.80	-12.2
20MAR89.AZ	13.93	-71.1	22.06	-198.0	23.31	-26.3	1.09	-166.8	-2.18	-199.6	-7.46	-236.8	-17.98	-257.7
20MAR89.BA	9.80	-45.9	25.23	-82.2	11.90	-130.2	-.65	-142.4	-3.04	-171.2	-2.95	-173.2	-2.29	74.3
20MAR89.BB	9.76	-27.3	27.20	-111.9	10.02	-103.5	-1.40	-135.4	-5.05	-174.2	-3.02	-172.7	-4.89	73.1
20MAR89.BC	4.05	-67.1	9.92	-94.6	8.00	-120.0	-.01	-145.2	-7.88	-171.4	-2.49	-175.3	-5.92	-247.4
20MAR89.BD	3.77	-78.8	7.68	-97.5	8.68	-91.6	1.30	-131.0	-2.15	-165.6	-5.78	-190.9	-7.56	39.6
20MAR89.BE	15.06	-92.1	18.43	-220.8	6.64	-109.2	-1.49	-136.9	-3.75	-161.5	-9.42	-171.7	-5.60	82.8
20MAR89.BF	13.75	-18.3	11.32	-94.6	5.87	-108.1	-2.00	-140.1	-2.25	-173.7	-1.84	-199.0	-12.57	-1.9
20MAR89.BG	7.73	-83.4	8.32	-95.4	5.96	-110.5	-1.40	-145.2	-3.77	-164.1	-1.62	-199.6	-7.91	3.6
20MAR89.BH	1.26	-89.1	4.59	-112.4	6.41	-168.1	-3.78	-176.4	-.88	-224.1	-16.33	-168.7	-19.12	-189.5
20MAR89.BI	14.26	-87.0	8.22	-85.8	14.31	-154.6	-1.18	-174.0	-.92	-142.8	-5.95	-189.6	-28.02	-263.5
20MAR89.BJ	13.24	-151.6	24.78	-224.8	5.11	-127.9	-.52	-172.3	-3.85	-234.2	-2.80	-229.5	-10.07	18.3

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (PITCH)

RUN	0.20		0.50		0.90		1.40		2.40		4.20		9.00	
21MAR89.AF	22.54	-113.5	14.59	-102.0	9.79	-122.9	4.82	-129.8	-1.56	-129.7	-4.89	-149.7	-6.65	-194.2
21MAR89.AG	25.22	-84.1	17.32	-106.7	9.74	-122.1	3.57	-125.2	-1.53	-133.2	-4.88	-146.5	-6.90	-194.4
21MAR89.AH	18.18	-92.5	11.77	-109.3	8.88	-104.9	3.87	-119.0	.19	-124.8	-2.77	-145.1	-4.75	-240.8
21MAR89.AI	24.29	-143.6	13.99	-94.8	8.18	-106.9	3.99	-117.2	-3.18	-120.3	-4.57	-148.6	-5.66	-229.9
21MAR89.AJ	22.77	-102.3	13.37	-97.7	7.43	-102.4	4.77	-109.6	-1.82	-123.2	-4.22	-130.8	-6.19	-201.2
21MAR89.AK	20.12	-78.6	11.63	-104.1	7.65	-99.6	3.82	-105.8	-1.59	-111.6	-3.87	-140.1	-5.32	-207.1
21MAR89.AL	16.11	-134.6	11.45	-114.1	6.09	-107.6	1.70	-105.7	-4.50	-114.4	-3.79	-146.9	-7.41	-258.6
21MAR89.AM	18.64	-104.6	10.83	-99.6	5.17	-94.1	2.98	-86.0	-.85	-127.6	-3.83	-148.5	-5.97	-267.2
21MAR89.AN	17.28	-67.2	10.13	-103.9	6.61	-93.1	3.89	-107.6	.63	-130.3	-4.28	-160.8	-5.46	-266.4
21MAR89.AO	22.27	-124.3	13.43	-121.5	7.69	-118.4	2.64	-138.1	-3.46	-142.9	-5.82	-167.1	-2.44	62.0
21MAR89.AP	18.75	-115.1	10.43	-93.3	9.09	-106.3	1.98	-142.2	-2.36	-146.7	-5.46	-171.5	-.94	24.7
21MAR89.AZ	24.17	-108.9	19.83	-105.8	9.69	-121.6	5.32	-129.1	-.64	-133.1	-6.61	-142.2	-5.59	-182.2
21MAR89.BA	18.20	-104.2	11.22	-109.2	6.40	-99.9	2.99	-97.7	.69	-121.4	-4.03	-142.6	-2.70	-214.7
21MAR89.BB	19.78	-104.3	11.51	-96.4	5.71	-96.0	2.97	-105.1	-1.00	-120.9	-4.31	-137.2	-2.64	-217.7
21MAR89.BC	20.22	-141.2	9.39	-113.3	6.10	-114.5	1.95	-123.3	-3.57	-139.9	-3.94	-158.9	2.64	62.7
21MAR89.BD	20.98	-134.7	10.83	-90.7	5.33	-104.5	2.43	-128.0	-4.19	-143.7	-5.44	-157.2	5.83	60.3
21MAR89.BE	22.62	-134.8	10.89	-111.5	5.84	-94.2	4.47	-100.5	-1.40	-125.6	-3.73	-134.4	-1.66	-213.2
21MAR89.BF	19.22	-89.4	13.16	-97.1	6.01	-92.2	4.61	-93.2	-1.57	-119.0	-4.42	-138.0	-1.51	-211.4
21MAR89.BG	19.01	-110.2	9.76	-103.6	3.41	-89.2	2.86	-95.5	-1.15	-117.6	-3.07	-138.6	-1.89	-231.1
21MAR89.BH	22.00	-91.7	9.54	-102.0	3.88	-85.9	4.37	-84.5	1.50	-128.9	-4.25	-145.0	-1.26	-233.2

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (ROLL)

RUN	0.30		0.40		0.70		1.80		3.00		4.00		7.00	
21MAR89.AQ	17.18	-63.4	11.08	-88.4	12.17	-104.8	.57	-119.5	-3.55	-144.5	-4.92	-161.6	-6.64	-204.3
21MAR89.AR	13.22	-101.2	18.83	-91.0	7.79	-111.3	1.46	-119.4	-1.67	-124.1	-6.18	-154.1	-7.50	-201.3
21MAR89.AS	14.40	-76.9	13.04	-59.7	6.84	-89.7	-.88	-126.0	-3.63	-153.7	-5.16	-176.8	-7.10	-253.4
21MAR89.AT	15.67	-66.3	16.41	-144.2	7.28	-109.9	.18	-130.9	-4.96	-155.0	-5.65	-175.2	-6.73	-254.3
21MAR89.AU	18.09	-73.5	10.80	-116.7	7.11	-120.6	-.59	-135.8	-2.95	-161.6	-3.00	-185.5	-3.85	28.6
21MAR89.AV	20.16	-93.8	10.34	-120.0	8.43	-119.2	-1.88	-135.5	-3.69	-160.2	-4.00	-184.6	-3.07	29.5
21MAR89.AW	11.72	-51.2	8.89	-128.3	7.57	-107.8	-.13	-145.1	-3.40	-155.8	-4.22	-180.7	-5.62	75.1
21MAR89.AX	14.70	-82.2	9.39	-46.4	17.14	-109.9	-.27	-144.6	-3.68	-167.2	-4.97	-182.6	-8.28	71.3
21MAR89.AY	19.73	-86.0	14.53	-66.4	6.35	-122.0	-.40	-143.6	-4.25	-156.4	-4.24	-179.1	-5.71	63.2
21MAR89.AZ	13.89	-95.0	12.66	-112.5	7.87	-113.8	-1.16	-125.0	-4.79	-143.2	-7.48	-149.9	-7.69	-186.6
21MAR89.BA	12.74	-58.9	22.48	-84.1	5.99	-117.5	-.72	-137.6	-4.37	-168.6	-6.86	-177.2	-11.42	64.4
21MAR89.BB	12.86	-75.9	9.44	-92.4	4.93	-112.8	-1.94	-135.7	-4.82	-161.7	-7.59	-198.9	-8.80	71.1
21MAR89.BC	15.45	-110.9	10.66	-94.9	6.83	-115.7	-3.49	-139.7	-6.77	-166.8	-6.99	-183.3	-11.01	67.5
21MAR89.BD	14.73	-74.9	9.88	-86.0	7.99	-114.4	.39	-134.4	-3.79	-171.3	-10.29	-197.8	-6.52	74.3
21MAR89.BE	18.23	-97.3	13.19	-107.2	6.48	-113.6	.22	-156.4	-3.63	-196.2	-11.48	-227.9	-10.74	52.9
21MAR89.BF	10.01	-55.7	7.14	-90.6	11.13	-111.5	1.57	-156.1	-3.89	-183.5	-8.56	-214.4	-13.29	24.7
21MAR89.BG	12.32	-96.1	7.08	-96.3	9.44	-113.5	-.50	-124.6	-2.56	-151.8	-4.24	-166.2	-5.78	64.9
21MAR89.BH	16.11	-74.4	10.89	-82.7	1.94	-101.5	-2.41	-130.4	-4.67	-158.6	-6.17	-183.3	-6.84	45.4

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (PITCH)

RUN	0.20		0.50		0.90		1.40		2.40		4.20		9.00	
21MAR89.BI	15.40	-100.7	12.22	-114.0	7.33	-106.8	2.71	-121.9	-1.85	-116.5	-5.35	-154.8	-6.10	-248.5
21MAR89.BJ	16.67	-95.1	13.63	-87.8	8.08	-113.3	3.12	-122.4	-1.87	-136.3	-5.34	-149.6	-5.52	-250.1
21MAR89.BK	19.44	-61.8	11.59	-91.7	3.89	-122.0	-.43	-125.9	-3.30	-140.0	-5.22	-173.1	-4.25	3.7
21MAR89.BL	22.04	-158.8	12.80	-132.4	5.69	-116.2	.52	-134.2	-4.05	-147.6	-4.37	-166.4	-1.78	13.6
21MAR89.BM	14.89	-92.5	10.77	-104.6	5.98	-112.8	.48	-127.1	-4.08	-141.4	-5.06	-164.6	-1.26	-14.8
21MAR89.BP	13.72	-95.4	11.11	-110.5	4.43	-115.0	1.06	-122.0	-1.78	-130.9	-6.50	-142.7	-6.56	-254.6
21MAR89.BQ	23.59	1.1	14.59	-107.4	5.87	-112.7	3.27	-124.1	-3.85	-133.1	-6.14	-147.2	-8.60	-245.4
21MAR89.BR	18.53	-84.8	11.61	-109.0	3.63	-107.3	1.73	-121.1	-4.48	-118.2	-6.44	-138.5	-7.28	-249.2
21MAR89.BS	19.41	-70.4	11.49	-101.8	6.92	-117.3	1.49	-140.9	-4.13	-145.4	-5.37	-169.6	-6.42	-6.9
21MAR89.BT	14.55	-84.7	16.05	-96.4	4.89	-122.4	1.40	-126.3	-4.68	-150.9	-5.62	-168.3	-6.60	-6.7
21MAR89.BU	16.79	-68.8	9.11	-79.8	3.62	-112.8	.03	-131.9	-4.84	-148.3	-5.72	-166.5	-7.59	-6.3
21MAR89.CA	19.35	-158.8	11.89	-99.2	5.45	-108.0	1.91	-117.0	-2.78	-122.2	-5.39	-145.0	-6.29	86.4
21MAR89.CB	23.05	7.5	8.43	-116.6	6.09	-101.9	2.86	-107.5	-2.55	-133.0	-4.99	-143.3	-3.93	-266.3
21MAR89.CC	19.44	-53.8	14.35	-101.8	6.01	-117.0	1.71	-128.2	-4.27	-136.1	-5.24	-168.2	-3.19	11.1
21MAR89.CD	13.15	-63.2	11.73	-114.1	5.16	-117.6	1.33	-126.3	-4.43	-143.1	-4.74	-166.0	-1.26	.7
21MAR89.CE	17.23	13.1	13.66	-87.5	5.26	-109.9	1.63	-119.3	-2.92	-142.2	-4.41	-164.8	-3.62	-.6

TABLE B-5. (CONTINUED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (ROLL)

RUN	0.30		0.40		0.70		1.80		3.00		4.00		7.00	
21MAR89.BI	12.39	-106.5	6.96	-44.9	14.34	-79.1	1.48	-132.1	-2.51	-156.4	-2.53	-172.4	-5.92	51.2
21MAR89.BJ	23.18	-85.7	8.19	-57.7	8.36	-94.4	1.39	-144.2	-3.35	-169.2	-3.34	-191.6	-6.37	-259.6
21MAR89.BK	22.69	52.3	11.42	-134.8	11.64	-130.3	-2.46	-145.6	-3.50	-169.8	-3.80	-201.4	-15.79	35.5
21MAR89.BL	15.23	-31.5	12.02	-94.5	8.46	-99.0	-2.02	-147.6	-2.81	-156.5	-3.73	-189.2	-3.32	-6.2
21MAR89.BM	12.91	-54.5	10.60	-122.6	11.75	-104.9	-.66	-147.6	-4.33	-169.1	-2.59	-207.2	-10.04	-10.9
21MAR89.BV	9.97	-89.3	12.72	-74.6	6.67	-104.0	-3.55	-127.1	-4.83	-162.3	-8.59	-171.8	-12.34	-255.3
21MAR89.BW	10.52	-43.5	9.42	-51.3	7.84	-108.8	-3.32	-144.8	-5.07	-141.6	-10.60	-174.9	-12.40	-268.4
21MAR89.BX	21.66	24.6	18.10	12.8	6.49	-116.6	-2.41	-140.6	-5.94	-146.0	-5.98	-180.6	-10.86	-269.8
21MAR89.CA	10.21	-66.1	14.94	-98.3	9.30	-110.9	-1.00	-130.7	-7.21	-165.4	-8.64	-197.4	-9.25	81.9
21MAR89.CB	8.63	-77.8	27.60	-29.3	13.49	-114.7	-1.26	-136.6	-8.69	-173.8	-5.83	-170.0	-10.84	-267.3
21MAR89.CC	12.67	-99.5	10.49	-78.3	8.85	-103.0	-.04	-131.7	-4.85	-165.8	-6.80	-178.7	-7.22	76.4
21MAR89.CD	12.12	-111.9	9.23	-91.2	6.67	-115.7	-3.50	-124.5	-5.09	-148.7	-9.80	-181.1	-4.28	66.1
21MAR89.CE	15.31	-130.8	10.96	-105.8	7.69	-116.2	-3.75	-127.2	-6.34	-166.7	-6.80	-160.9	-9.68	68.1

TABLE B-5. (CONCLUDED)

FREQUENCY (RAD/SEC)

GAIN (dB) PHASE (DEG) OF YPYC (SPEED)

RUN	0.10		0.30		0.50		0.70	
21MAR89.BN	15.88	-187.7	9.17	-82.8	5.03	-134.8	3.31	-147.1
21MAR89.BO	22.18	-185.2	10.54	-73.0	11.93	25.9	1.08	-142.2
21MAR89.BP	10.17	-104.9	7.99	-180.1	4.45	-168.5	-8.86	-212.4
21MAR89.BQ	25.60	-179.6	13.45	-81.1	7.07	-134.2	9.41	19.1
21MAR89.BR	15.55	-176.7	12.20	-134.8	3.73	-92.6	5.04	-149.6
21MAR89.BS	14.69	-193.9	11.11	-151.8	7.27	-149.4	5.15	-167.9
21MAR89.BT	22.07	-166.0	11.21	-105.6	-.25	-92.2	-1.32	-118.6
21MAR89.BU	14.76	-172.7	6.79	-116.0	4.39	-107.3	2.96	-109.0
21MAR89.BV	27.54	-113.2	8.69	-150.2	8.29	-133.1	5.50	-127.9
21MAR89.BW	20.26	-149.0	11.38	-128.6	4.47	-135.1	2.93	-134.1
21MAR89.BX	24.65	-123.1	8.61	-143.5	6.29	-129.2	-5.03	-89.5
21MAR89.CA	15.83	-141.1	5.67	-116.4	2.46	-131.3	2.00	-157.2
21MAR89.CB	20.03	-105.1	9.74	-162.1	2.41	-129.3	-1.84	-155.5
21MAR89.CC	17.12	-255.8	6.02	-167.0	-2.49	-136.1	-4.85	-174.0
21MAR89.CD	13.01	-146.1	6.27	-149.0	1.69	-125.9	-2.80	-150.9
21MAR89.CE	12.77	-126.4	5.09	-88.5	1.32	-132.3	-3.68	-164.4

TABLE B-6. TRANSCRIBED PILOT COMMENTS

Following are transcribed pilot comments from the LAMARS simulation. Comments are presented sequentially by run number; configuration and HQR are also given for reference. The raw pilot comments have been edited for clarity. For several runs, particularly in the early stages of the simulation, the tape-recorded comments have been lost. It was standard practice during the simulation for the experimenters to note a few key words for each configuration, and in these instances, the key words are used here in lieu of actual transcribed comments. Such runs are indicated by enclosing them in boxes.

RUN NO.	PILOT	CONF.	HQR	COMMENTS
14-19	M			[No comments recorded.]
20-21		A	4	Commands go beyond desired limits.
22-23		H	4	Less sharp-edged than last case.
24-27				[No comments recorded.]
28-29		1A	4	Roll tougher than pitch.
30-31		4H	5	Both axes hard to track.
32-33		6C	7	Pitch/roll disharmony, pitch oscillatory.
34-36				[No comments recorded.]
37-39		1	2-1/2	Sometimes goes outside desired but can get it back.
40-41		2	3	Not too different, but a little more imprecise.
42-43		4	4	Lacked predictability, almost 4-1/2
44-45		6	6	Backed off in sensitivity and performance; 7 or worse if aggressive.
46-48		H	2	Large bank commands.
49-50		C	4-1/2	No precision, wallowing. Can't tell if it's forcing function or pilot.
51-52	M	1	2	Easy.
53-54		H	3	Sharp commands make it tough.

TABLE B-6. TRANSCRIBED PILOT COMMENTS (CONTINUED)

RUN NO.	PILOT	CONF.	HQR	COMMENTS
55	M	T6	1	Almost an HQR of 0.
56-57		1H	3	Not too tough, can get back to desired; maybe pitch worse, but both almost same.
58-59		4H	5	Lack of precision, bobble are problems with pitch.
60-61		4C	5-1/2	Flyable but in adequate range. Roll wallows.
62-63		4HT6	6	Workload added with throttle.
64-65	V	1	4	Within desired, lack of forward authority, slight PIO tendency.
66-67		2	4	Tendency to overcontrol, desired performance attainable.
68-69		4	5	Fair amount of lead compensation, need to back off to try to get desired performance.
70-71		1	2	Good tracking.
72-73		6	7	Almost uncontrollable, very PIO prone. Marginally adequate performance -- stay out of loop.
74-75		A	2	Pretty nice; little high breakout force in roll.
76-77		H	4	Minor but annoying deficiencies.
78-79		C	8	Controllable. Adequate performance attainable. Extreme lead compensation, PIO prone.
80-81		T6		[No HQR or comments taken; training runs.]
82-84		1A	5	Just adequate. Pitch was more trouble.
85-88		1H	4	Edge of desired; both axes balanced, pitch is maybe a little higher workload.

TABLE B-6. TRANSCRIBED PILOT COMMENTS (CONTINUED)

RUN NO.	PILOT	CONF.	HQR	COMMENTS
89-90	V	2H	4	Pitch more demanding.
91-93		4H	5	Can't be aggressive in pitch, tend to overcontrol in roll.
94-95		1A	3	Tracked well in fine tracking, pitch/roll harmony good.
96-97	S	1	3	Desired performance; no problems.
98-99		2	3	Not a whole lot of compensation.
100-102		4	5	Compensation increased. Couldn't get desired performance.
103-104		H	3	Minimal compensation.
105-106		A	2	[No comments recorded.]
107-108		C	6	Got adequate performance. Compensation went up -- anticipation required.
109-111		1A	5	Considerable compensation, adequate performance attained, roll dominates.
112-114		2A	4	Control harmony good. Pitch required more force.
115-117		2H	6	Pitch problems; got adequate performance.
118-119		4H	6	Extensive compensation in pitch -- time delay; roll more dynamics.
120-121		1C	7	Controllable. Roll problems -- damping low.
122-124		1A	4	Desired performance with moderate compensation. Both axes pretty good.
125-126		4C	6	Adequate performance with extensive compensation. Roll worst but pitch not great.

TABLE B-6. TRANSCRIBED PILOT COMMENTS (CONTINUED)

RUN NO.	PILOT	CONF.	HQR	COMMENTS
127-129	S	2H	4	Got desired performance with moderate compensation.
130		T6	1	Almost second nature.
131-133		2HT6	6	Got adequate performance only. Airplane alone is great, but added workload of throttle drives the rating.

Date: 17 Feb. 1989; Pilot B

Runs 134-136; Conf. 1; HQR 2:
The aircraft was controllable, able to meet satisfactory performance. It had good characteristics, and I didn't feel that I had to compensate to achieve desired levels of performance.

Runs 137-138; Conf. 2; HQR 2-1/2:
It was controllable, satisfactory performance. Had to compensate very slightly for an overshoot at the end of the stick pulse.

Runs 139-140; Conf. 4; HQR 4:
The performance was adequate, nearly satisfactory, had several minor excursions into the adequate-only range. Would say that it has some deficiencies, and I did have to do a little compensation for the overshoot tendencies where it seemed tc be lightly damped.

Runs 141-142; Conf. 2; HQR 2:
On both runs we had satisfactory performance, pilot compensation was not a factor for this, although the system seemed to be damping itself to a lower value than your initial stick input. That seemed to assist in keeping the system within performance rather than force additional compensation.

Runs 143-145; Conf. 6; HQR 5:
The aircraft was controllable, however, it was not able to be controlled within the desired performance parameters. It was able to be controlled adequately, however. There is a problem flying the airplane very aggressively as it tends to excite the short-term mode which makes the aircraft much less controllable. Flown smoothly, less aggressively, and tolerant of a lower level of performance, it's much more controllable and flown smoothly without exciting that mode, I would say the performance was more that of a 4. However, due to the possible excitation of the short-term mode, I'd have to rate it about a 5 if you get yourself into the position where you possibly excite that mode.

TABLE B-6. (CONTINUED)

Runs 146-147; Conf. A; HQR 2:
Run was very benign, very controllable, had very good qualities, but did require pilot input to make the performance, but no compensation required.

Runs 148-149; Conf. H; HQR 2-1/2:
It was controllable and was able to obtain satisfactory performance. However, it did require very slight pilot compensation. Although not quite the degree required for a rating of 3.

Runs 150-153; Conf. C; HQR 4-1/2:
Adequate performance was obtainable. However, satisfactory performance was not. The pilot did have to make a more than moderate but not quite a considerable amount of compensation for the lack of damping at the end of the roll and had to anticipate.

Runs 154-156; Conf. 1A; HQR 2-1/2:
Satisfactory performance was achieved. Pilot compensation was not really a factor but the workload was increased somewhat with the two axes.

Runs 157-159; Conf. 4H; HQR 5:
I was able to obtain satisfactory roll performance. However, the pitch performance was only adequate. It has a short-term mode that's easily excitable. However, if you're willing to accept adequate performance rather than attempting to obtain the satisfactory level, this is only moderately objectionable. It did require a moderate level of pilot compensation to avoid entering this mode.

Runs 160-161; Conf. 2H; HQR 3-1/2:
Majority of the time I was able to obtain desired performance level, occasionally exceeding the desired level into the adequate range in roll. No special pilot compensation was necessary. It did not seem to have any annoying characteristics.

Runs 162-165; Conf. 2C; HQR 4:
I was unable to obtain satisfactory performance. However, performance was adequate in both axes, primarily due to the poor performance in the roll axis. The deficiency is somewhat minor and does not excite easily, and does require moderate compensation to obtain that level of performance.

Runs 166-170; Conf. 6H; HQR 5-1/2:
I was only able to obtain adequate performance with one excursion outside of that performance level category. There is an objectionable deficiency in the pitch mode in that it's very easily excitable and it required extensive compensation to avoid exciting that mode.

TABLE B-6. (CONTINUED)

Runs 171-173; Conf. 4C; HQR 5:
Unable to obtain satisfactory performance. However, performance level was adequate. The deficiencies are minor, but they do require a fair amount of compensation.

Date: 21 Feb. 1989; Pilot M

Runs 174-175; Conf. 1; HQR 2:
That configuration is just satisfactory without improvement. It's very, very easy to correct any errors here. They never seem to get very large. Once or twice it maybe gets just to the edge of desired but no problem correcting it whatsoever. It's just, there's a lot of activity, obviously, it's rather high frequency and no real pilot compensation required to keep the thing under control. In fact, you kind of back off on it a little, maybe just kind of watch the lines squiggle around and keep it easily within the desired boundary, and then tighten up just a little and keep it pretty tight.

Runs 176-177; Conf. 2; HQR 3:
That configuration is not as crisp and sharp, it seems, as the one I flew before. It's satisfactory without improvement and I got desired performance all the time. There were a couple of little spikes again on the edge of desired, but really no difficulty getting it corrected. Just a little bit of a lack of precision there and it seems to me, I had to be a little bit more on my toes ready to respond to the forcing function. There is a little bit of compensation required. So that's up to an HQR 3.

Runs 178-180; Conf. 4; HQR 3:
I ran that one three times because the first time I flew it, it was, the very first run there was a little bit of a bobble or inability to be very precise about where I put the nose of the aircraft. Spent a little more time than I'd like outside the desired bound or on the edge of the bound. It was a little bit hard to control the thing. The second run seemed a lot easier, like I was able to do a little better job and at least I didn't spend as much time out of the desired bounds. So, I ran it a third time to look, and the third one was somewhere between the first two. It's not a great joy aircraft to fly because it is a little bit difficult to get the precision out of it. There is a tendency too, for the nose to bobble a little bit and you have to kind of be aware of that, and then correct it. But it was not to the point of saying that the deficiencies warrant improvement. It just wasn't all that bad. And, I'm really, even though I know there were some time delay or some initial sluggishness or lag in there, I could see that it just wasn't enough to really, really degrade my performance.

TABLE B-6. (CONTINUED)

Runs 181-182; Conf. 5; HQR 5:
The low damping ratio was really obvious on tracking in that configuration. There's an interesting case because, if you could be real careful with it and not excite that mode, it actually wasn't all that bad to try to perform the task. In fact, desired flight performance was attainable most of the run. Certainly adequate performance was attainable with tolerable pilot workload. The low damped mode, you got it excited enough, frequently enough just to make it not worthwhile, just to make it annoying. There's just no question that the deficiencies warrant improvement, that it's Level 2 aircraft. In fact, as far as performing the task, the performance I was pretty happy with overall. The biggest problem was just that low damping ratio, and that's I consider moderately objectionable. It's almost level of being very objectionable except, if you knew not to really get in there and chase it, you could keep it from getting too bad.

Runs 183-184; Conf. 4; HQR 3:
This configuration was on the border of not being satisfactory without improvement. There's a definite lack of precision with it, but it's still not hard to keep the aircraft in the desired bounds. A couple of times per run, it'll get outside desired, but I can immediately just put in a little larger input and it'll get right back in. I really don't have much difficulty keeping it within the desired performance. There is a little bit of bobble, or lack of precision, right at around zero, but it's not enough to really degrade it all that much. I can really still fly the aircraft pretty well. But, it does have a little bit of a mildly unpleasant deficiency with the little bit of lack of precision. Minimal pilot compensation required.

Runs 185-187; Conf. 6; HQR 6:
The low damping is really obvious. It's really obvious that if you try to track the forcing function very tightly, you really could get yourself into what feels like a PIO, it's not obvious whether it's that or just the damping ratio is so low that you can't sort it out. All you can tell is that it's something, you get sustained oscillations and there's a tendency to want to back off. If you don't back off, you can still get the performance to be desired to adequate, you very seldom go outside of adequate or maybe never go outside the adequate bound. I ran it three times and I don't think I went outside of adequate on the third run. But there were times that I was outside of desired, and even to get within desired was a lot of work. It's not satisfactory without improvement but I'm not sure the deficiencies require improvement. I don't think I'm at the level of being Level 3 because I got the adequate performance, even though the workload's high, high but tolerable.

Run 188-189; Conf. A; HQR 2:
No problem really at all doing the task with this configuration. The aircraft was satisfactory without improvement. I think I flew it a little bit differently between the two runs, the first run trying to be anticipating the forcing function and trying to be on top of it, and put in a little smoother inputs, and in the second run just responded when the thing moved, I put in whatever was necessary to correct and, it was very tolerable. No problems, it was a very crisp, easy to ` aircraft.

Runs 190-191; Conf. [illegible] 2:
That configurati [illegible] was not noticeably different from the previous case. Any roll errors are easily corrected. It's assembly really not quite as sharp and as crisp and smooth as the previous configuration. But, boy, the differences are so small that I have no difficulty doing the task. Really no pilot compensation required to get desired performance.

Runs 192-193; Conf. C; HQR 5:
The configuration I just flew is clearly very sluggish, hard to be precise whatsoever with it. The task is still do-able, most of the time I could get, well, always I could get adequate performance, most of the time I could get desired. It just tended to be from side-to-side on the desired performance bound. The sluggish characteristic is clearly not satisfactory without some improvement but is still flyable, is still do-able, it requires considerable pilot compensation to get desired and there are a couple times there, in both runs, maybe two times per run, where I really felt like I was on the edge of losing it and getting out of the adequate bound. I had to work really quite hard to get it back in.

Runs 194-195; Conf. 1A; HQR 3:
The configuration was not too tough to handle. There were some times when you get on the edge of desired performance, either pitch or roll, and you tend to kind of lock in on that one, on that axis and try to work on it. Then the other one ends up going to the edge of desired performance as well. But, it's very easy to get correction in either axis. There are no obvious deficiencies in any way in the aircraft, nothing really objectionable about the aircraft. There is pilot compensation required though it's not a lot, to try to get desired performance. The primary compensation, I'd say, in that case, is just learning to separate out which axis is getting away from you and not try to focus in on it so much that the other axis runs away. But, it's really just nice and crisp and no real problems with it.

Runs 196-197; Conf. 2H; HQR 3-1/2:
That configuration is a little bit tricky. It's a little less forgiving if paying too much attention to one axis. You have to

really kind of stay on top of it and there's no obvious problem with it. It's just, you tend to be at the edge of desired in pitch and roll, maybe a little more than I'd like to be. Sometimes it gets out of desired in one axis or the other, but it's pretty crisp in getting it back. There's really no obvious deficiency in the aircraft characteristics themselves. But, it's still just a lot of work, and I think the driver in the HQR here, the amount of pilot compensation required for desired performance in both axes is somewhere between minimal and moderate.

Runs 198-199; Conf. 2C; HQR 6:
There's a definite difference in the characteristic of the pitch and roll responses there. The pitch response is nice and crisp and sharp, sometimes almost too crisp and sharp. And the roll is like trying to fly a whale. The thing just doesn't want to move very fast in roll and it's harder where you have to put doublets into the roll axis, which is what's required to fly that. Roll is always wallowing back-and-forth between the desired limits, that is, just outside the desired limits. A couple times I'm on the edge of the adequate limits in roll and trying to pay attention to that would let the pitch get away from me. And it was tough just to fly the configuration primarily because of that really low roll damping. I'm almost on the verge of saying it's not a tolerable pilot workload. I got adequate performance, but a lot of workload. Very objectionable deficiencies, adequate performance in roll, required extensive pilot compensation.

Runs 200-201; Conf. 4H; HQR 4:
I get a little bit tired on those so I didn't do as well as I thought I was able to do on those configurations, so I was on the edge of desired with both pitch and roll. In fact, a couple of times, one or the other axes got away from me. It seemed like I was having to put a lot of compensation in to make sure that I got the desired performance. It's not quite satisfactory but it's on the border. It was not satisfactory without improvement. It required moderate pilot compensation to keep the desired performance balance. But neither axis was really notably bad.

<u>Date: 21 Feb. 1989; Pilot V</u>

Run 202; Conf. 1; HQR 3:
I'd say it was satisfactory without approvement. Fair, some mild deficiencies. Slight bit of compensation required. Had to give it just a little bit of lead on stopping to track accurately. Otherwise, it would overshoot just a bit.

TABLE B-6. (CONTINUED)

Runs 203-204; Conf. 4; HQR 5:
Is adequate performance attainable with a tolerable pilot workload? Yes. Is it satisfactory without improvement? No. And I don't really think we kept it within desirable, I'd say moderately objectionable deficiencies and adequate performance requires considerable pilot compensation. Initially it was difficult to get the command input required and then you had to provide a lot of lead or it would overshoot. If you reduced your command too quickly it all came out at once and fine tracking was pretty near impossible.

Runs 205-207; Conf. H; HQR 2:
I think the breakout force is a little high, which makes it difficult to do the very, very fine tracking. As soon as you get any input in, because you overcame the breakout, you seem to be just a little too high. You want to overshoot a little. Otherwise, it's real good tracking, really negligible deficiencies. Very little tendency to overshoot. Had very good fine tracking characteristics.

Runs 208-209; Conf. C; HQR 7:
This is very roll PIO prone. Took a lot of lead compensation in order to stop the command in adequate time. Tended to overshoot most of the time. And, I do not really think adequate performance was attainable with tolerable workloads. I'll say NO to that. Had major deficiencies. It's very oscillatory.

Runs 210-211; Conf. 1A; HQR 3:
I'd say that configuration was satisfactory without improvement. It had some mildly unpleasant deficiencies. A little bit of trouble catching it aggressively in pitch. Fine tracking in pitch and roll, both good. No problems tracking in roll. Very little tendency to overshoot in either axis.

Runs 212-213; Conf. 4H; HQR 6:
It tended to be oscillatory in roll. Sometimes difficult to settle down oscillation. It seemed to be difficult to track in pitch and, then when you did track, it was generally a little oscillatory. I'd say it's not satisfactory without improvement. It's a very objectionable, but tolerable deficiency.

Runs 214-215; Conf. 2H; HQR 4:
It needs a little bit of improvement and minor but annoying deficiencies. Tended to have a little bit of overshoot characteristic in roll and in pitch it was a little bit hard to capture at times. But, once you caught it, it was possible to do some tracking with it.

Runs 216-217; Conf. 2C; HQR 8:
Adequate performance not attainable but tolerable pilot workload. And, it's really a combination, you know, if I was just rating the

roll axis in combination with pitch, it would definitely be a 9. The pitch axis was better. Its major deficiency was in roll. Took almost no sideways roll input was controllable really. It was very small inputs. I could compensate, if I had to make any large excursions, I could not really stop the excursion until it overshot by more than what the original error was. And, I tend to just get into a continuous roll oscillation. I was continuously chasing in roll, very difficult to stop in any given point and, when you try chasing things, your inputs just tended to get larger and larger. I was doing full opposite direction stick deflections just trying to stop it in the correct place. And, with very limited success.

Runs 218-219; Conf. 4H; HQR 5:
It was not satisfactory without improvement, which makes it Level 2 and I'd say adequate performance requires considerable pilot compensation. It was very easy to over-control in roll and pitch was sometimes difficult to track. For small corrections, they were pretty easy in both axes but large corrections were very difficult.

Runs 220-221; Conf. 1A; HQR 3:
I thought that was satisfactory without improvement. And, I'd say minor pilot compensation required for desired performance. A little bit of overshoot sensitivity in roll. But, otherwise seemed to track really well.

Runs 222-223; Conf. 6H; HQR 8:
On that one the roll was very controllable. The pitch was near uncontrollable. Any time you made large pitch reversals, you got huge oscillations. Reversals always led to PIO in pitch and I would say it's Level 3, adequate performance is not attainable for tolerable pilot workload. I'd say because of the pitch, it's a considerable pilot compensation required for roll and pitch.

Runs 224-225; Conf. 2C; HQR 8:
In those runs, roll was the most difficult task. And, in general, it was impossible to do fine tracking, you tended to put in a roll angle and then it's a very, very large one to stop it, which generally then resulted in overcompensating. It took off rolling the other way. It appeared that if I put no roll input in, there would probably be smaller errors. Several times, needed to release the controls to regain lateral control. Adequate performance not attainable with tolerable pilot workload. I'd say control is an issue and lateral.

Run 226; Conf. T6; HQR 3:
[No comments recorded].

TABLE B-6. (CONTINUED)

Runs 227-228; Conf. 1AT6; HQR 5:
That other task really interferes with your concentration on the primary tracking. Even a quick glance over there, or even trying to use it in your periphery, really does affect it and I'd say degrades your overall performance to the point that I cannot achieve satisfactory performance without improvement. And, I'd say it makes it kind of moderately objectionable. Requires some considerable pilot compensation, mostly due to task saturation. The dynamics themselves are fairly good, rating it from a task point.

Runs 229-230; Conf. 2HT6; HQR 7:

I'd say adequate performance is not attainable with tolerable workload. Deficiencies require improvement. Controllability was not in question. And, the compensation was not so much in a sense of overall dynamics but the amount of time needed to spend on each of the three tasks really degraded performance. I don't think I was really able to keep any of the three parameters within desired, they were all of the adequate level.

Date: 22 Feb. 1989; Pilot V

Runs 231-232; Conf. 1; HQR 2:
It was satisfactory without improvement. Negligible deficiencies, pilot compensation was not a factor for desired performance. Very easy to track. Probably a little minor difficulty with fine tracking, to make very, very precise inputs, you didn't really see much response. But otherwise, it was very easy to track.

Runs 233-234; Conf. 2; HQR 4:
This mode could use a little bit of improvement. It had some minor, annoying deficiencies where it seemed like the forces were out of phase with the pitch rate input. You could generally catch it, but then you would feel an oscillation and force that seemed like it was taking over and would reduce your command. Tracking was fairly good. Desired performance requires moderate, it definitely required some compensation.

Runs 235-236; Conf. 4; HQR 5:
On this one it was difficult to predict your command size. If you went too large you got very oscillatory, too small you had difficulty tracking the target. Precision tracking, pretty difficult. Took a lot of lead compensation. So I'd say this is not satisfactory without improvement. Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation.

Runs 237-238; Conf. H; HQR 2:
This is something very good. It does not need any improvement. Once

again, breakout, I think, was just a little high, making it just a little difficult to make very small, like 1 or 2 degree corrections. But otherwise good negligible deficiencies. Pilot compensation is not a factor. You can pretty much try to drive it where you wanted it.

Runs 239-240; Conf. B; HQR 6:
There is adequate performance attainable with tolerable pilot workload. Does need improvement. I'd say it's very objectionable but tolerable deficiencies. Adequate performance requires extensive pilot compensation and you could not put in large inputs or you greatly overshot. You had to moderate your input size and you had to lead it as much as you could to try to get it to stop in the same point that you desired. Really didn't get much opportunity to fine track.

Run 241-242; Conf. 2H; HQR 3:
That's satisfactory without improvement. Fair but moderately unpleasant deficiencies. There were some times where there were excursions beyond the desired level but overall, you could generally track it fairly well. It was fairly demanding.

Runs 243-244; Conf. 4A; HQR 4:
It needed some improvement. In pitch it seemed like fine tracking was good but it would get away from you. It would seem to get a little large at times. You try to catch it, had a little difficulty, then it would track well. Roll was kind of step-ish. You put an input in and it would want to stop very abruptly on it. Desired performance requires moderate pilot compensation.

Runs 245-246; Conf. 1B; HQR 7:
I don't think adequate performance was attainable with tolerable pilot workload. So I'll say there were major deficiencies and controllability was not in question. But in the roll axis, it was so oscillatory and so lightly damped you could not stop anywhere you wanted. There was the authority to chase it but you're always going to overshoot unless you provide tremendous lead compensation. And, even then, it was impossible to predict exactly where it was going to stop.

Runs 247-248; Conf. 4AT6; HQR 7:
Adequate performance not attainable with maximum tolerable pilot workload, controllability not a question. There seem to be a lot of PIO tendencies in pitch, a lot more than I thought just doing the sensitivity analysis, which made it very difficult to control. At times it seemed to be enough power but then you'd really PIO it just trying to lock in, which really detracted from even being able to do the throttle task. Roll was fairly good.

TABLE B-6. (CONTINUED)

Date: 22 Feb. 1989; Pilot M

Runs 249-250; Conf. 2; HQR 2:

No real problems doing the task whatsoever. It's very easy to get desired performance in the desired range all the time. There is no obvious deficiency about the aircraft. Perhaps there's a little bit of a lack of precision on the very, very fine tracking. Kind of noticeable as there's some initial abruptness and washout in the configuration but no difficulty flying it.

Runs 251-252; Conf. 4; HQR 3-1/2:

That configuration was not quite as precise as the case before, a little bit of a lack of precision on it and sometimes it seemed like it almost got away from me, barely outside the desired range. I could always get it back in but I couldn't be very accurate with it. Not any real obvious problems with it, no obvious lack of damping, no shortcomings like that but just couldn't be very precise. I could get desired performance if I kind of stay on top of it. So, somewhere between minimal and moderate pilot compensation to get desired. I'm getting desired but somewhere between minimal and moderate. So, I'm torn between a 3 and a 4. So, I think I'm going to give it one of those horrible half ratings, a 3.5.

Runs 253-254; Conf. A; HQR 2:

No problems with that one whatsoever, no deficiencies that are noticeable. In fact, I kind of tried in some cases, trying to put a lot of inputs in, small inputs to keep it around zero. And then I tried other times to just kind of pulse the stick when I saw it move, and it didn't seem to matter how I flew it. It did pretty well. No real problems flying that.

Runs 255-256; Conf. C; HQR 6:

This configuration clearly has an extremely strong lack of damping. There's just no damping in there at all, whatsoever. And, when you put an input in, you've got to be sure you not only take it out but you put in a countering input, a doublet. And, every time at the start of the run, it took me a few seconds to remember how to fly the configuration all over again. It's definitely not satisfactory without improvement. Even though I was getting desired performance most of the time, adequate a lot, it still has the lack of damping, which to me is very objectionable. It is extremely difficult to keep from, in fact, getting into the loop and almost PIOing that configuration. A couple of times I over-controlled a little bit and almost got into a PIO, what felt like a PIO.

Runs 257-258; Conf. 2A; HQR 3:

Really pretty much a piece of cake. There's no obvious problem with pitch or roll. Both axes got to the edge of desired and even sometimes skirted a little bit out of desired. I understand that

with the dual axis it's going to happen. And, so it caused a little bit more workload than maybe either axis alone. But they're both so easy to control that there's really no great compensation required to keep within desired. The ride is maybe a little bit sharp edged in both pitch and roll.

Runs 259-260; Conf. 4A; HQR 4:
Roll in this case was just not any real problem. The difficulty in pitch was not obvious, I didn't see it when I was doing the sensitivity checks. But I couldn't be precise. It always seemed to kind of wallow around the target around zero. I couldn't seem to keep it where I wanted to. I had a little bit of difficulty with that. Sometimes I'd go outside desired range but I could get it back within desired relatively easily. Really wasn't that much trouble to fly the pitch axis either. But there was this lack of precision, which I would call a minor but annoying deficiency.

Runs 261-262; Conf. 1C; HQR 7:
This combination of really snappy pitch and really doggish roll was a real problem to fly. I thought when I was doing the sensitivity checks that the harmony would be a problem but it was really not. Pitch was almost second nature in comparison to the roll. The roll really gave me some problems there at times. I got adequate performance but I was certainly on either side of adequate, both sides of adequate, in roll, regularly. And, if I tried to really concentrate on the roll, the pitch would get away a little bit. So, while I got adequate performance, and it was attainable, it was not attainable with what I would call a tolerable pilot workload.

Runs 263-264; Conf. 4C; HQR 7-1/2:
The roll axis is still incredibly sluggish. Very, very difficult to stop an input when I put an input in. Difficult to remember to do that, especially when pitch gets away from you a little bit. On the two runs, there was a point, especially in the first run, where it looked like maybe I got some large spikes in the commands in both pitch and roll simultaneously and it really felt like I was on the edge of losing it. I was, my thumb was finding the Vader button on the handle at the time, of the joystick. And, as a result, that run was a little more exciting than the second run. That one wasn't quite so bad. But neither was what I'd call fun. I don't think adequate performance is attainable with tolerable pilot workload. I think it has major deficiencies, especially in roll. But, even in pitch on this one, it seemed very difficult to keep it within desired performance. And, on the basis of the second run, it would probably be a 7. On the basis of the first run, it would probably be an 8. So, I'm going to split the difference and make it a 7 and one half.

TABLE B-6. (CONTINUED)

Runs 265-266; Conf. 6A; HQR 7:
The pitch axis is extremely low damped and very obvious. It's very easy to excite it. Roll axis is almost just like a little nuisance there, really no problem at all whatsoever keeping the roll axis under control. The roll axis almost wasn't even noticed, it's swamped by the magnitudes of the pitch oscillations when I accidentally excite it and sometimes I have to 'cause I get outside of adequate. So, I'm not getting the adequate performance with a tolerable pilot workload - that the damping is just intolerable. I think if I were in flight, and if I didn't know that this is a condition I was going to get, and I got this, I might be looking for the button to eject because it's just not acceptable. Controllability is not in question.

Runs 267-268; Conf. 2AT6; HQR 5:
Pitch and roll really not too much trouble. Neither is the throttle. Unfortunately, all together they're a lot of work. No obvious deficiencies in any axis. As usual, if you don't pay attention to the throttle, it'll run away on you. And, if you do pay attention to the throttle, either pitch or roll will run away a little bit on you. So, adequate performance attainable with tolerable pilot workload? Yes. Is it satisfactory without improvement? Not the way it works out right now. I simply couldn't keep desired performance in all boundaries, and that's not satisfactory without improvement. I wouldn't say that it's very objectionable deficiencies the way it stands because there's no obvious deficiency in any axis. It's simply a lot of work. It's probably moderate deficiencies. I was certainly getting adequate performance.

Runs 269-270; Conf. 4AT6; HQR 5:
Another three axis run and, I don't know, maybe if I ran it a couple hundred times, I'd start not minding those too much. I had some difficulty. The first run I think I paid more attention to pitch and roll and I'd look over and throttle would be way off, even the adequate range. Or, on the edge of adequate. And, the second run, I tried to keep the throttle in a little more but wasn't able to do it. So, the combination is not satisfactory without improvement. I'm still having difficulty getting the whole task overall done. No single axis, no single area seems to be the driver in my ratings. It's somewhere between moderately objectionable and very objectionable overall just because of the amount of workload. It's difficult to do. Adequate performance requires between considerable and extensive.

Date: 22 Feb. 1989; Pilot V

Runs 271-272; Conf. 2A; HQR 2:
I thought performance was satisfactory without improvement. So it's

TABLE B-6. (CONTINUED)

Level 1 and I thought it was good, negligible deficiencies. I didn't have any real problem. My tracking was fairly easy, very predictable.

Runs 273-274; Conf. 2AT6; HQR 4:
With the three axis task it was difficult to maintain everything within the desired boundary. I'll say there was some improvement necessary, minor but annoying deficiencies. I think just to concentrate in pitch/roll, I had some trouble maintaining the throttle task.

Runs 293-294; Conf. 2; HQR 2:
Those were real good to fly. Biggest difficulty, extremely fast reversals, tended to lift you out of the seat a little which made it a little difficult to track. Overall, though, pilot compensation not a factor for performance.

Runs 295-296; Conf. 5; HQR 5:
This one is not satisfactory without improvement. Moderately objectionable deficiencies. Adequate performance requires considerable pilot compensation. Initial inputs or reversals were very responsive and then it starts oscillating, gets very laggish and makes it difficult. Very fine tracking when you were really close was not too bad and the initial movement and direction was really good. But, when you make quick reverses, you got very large input then it died out very rapidly. That was difficult to predict exactly where you were going to head off.

Runs 297-298; Conf. A; HQR 2:
That one was very good. Only minor discrepancy I think is the [high] breakout, which I've gone over before. It tracks very easily.

Runs 299-300; Conf. B; HQR 6:
This one definitely needs improvement. It requires considerable compensation on the part of the pilot. Any time after putting an initial input in, you must immediately go reverse with the stick to stop it and you must do it very quickly. Very objectionable but tolerable deficiencies. Adequate performance requires extensive pilot compensation.

Runs 301-302; Conf. 2B; HQR 7:
Adequate performance was not attainable with tolerable pilot workload. Has major deficiencies primarily in roll. The roll requires so much compensation that it also makes it very difficult to control the pitch. Pitch characteristics seemed fairly good but they were totally overwhelmed by the roll.

Runs 303-304; Conf. 2T6; HQR 4:
Some improvement is necessary. And I'll say minor but annoying deficiencies. Desired performance requires pilot compensation. The

throttle and the pitch themselves both had good characteristics, the two in combination tended to make the task more difficult and it was hard to get exactly where you wanted.

Runs 305-306; Conf. 5T6; HQR 7:
Adequate performance was not attainable with tolerable pilot workload. And, the pitch was very PIO prone and you had to back the command out. If you tried to back the command out at all, providing lead, it stopped, almost always short of where you want to go. It's very difficult to predict. I'd say adequate performance not attainable with maximum tolerable pilot compensation.

Date: 23 Feb. 1989; Pilot V

Runs 307-308; Conf. 1; HQR 2:
Compensation by the pilot was not really a factor for the desired performance, desired performance was maintained at all times. Had negligible deficiencies.

Runs 309-310; Conf. 4; HQR 3:
We'll go with desired performance. I felt like I got that most of the time. There were some excursions outside the tolerance but that was on the initial forcing function. Other than that, I felt I got desired performance all the time. Compensation did increase. I wouldn't consider it moderate, though we'll say it was a minimal pilot compensation.

Runs 311-312; Conf. 6; HQR 6:
I felt like I had adequate performance on all modes, although there were some excursions outside the 10 degrees but that was due to the forcing function. Extensive pilot compensation and I found myself changing my way of maintaining the required performance level. But I did get adequate performance. I found myself, rather than trying to really tense up and make really small, real precise corrections, it was make a big one and then just kind of release the stick, and watch it kind of settle out, and then make a small, smooth input, rather than an abrupt, precise input. Because, otherwise, the delay and the damping, it would just make it worse.

Runs 313-314; Conf. H; HQR 3:
I feel I had minimal compensation to maintain desired performance in there. Some unpleasantries but very, very mild.

Runs 315-316; Conf. C; HQR 5:
I felt like I got adequate performance all the time, I was just kind of on the outskirts of desired. Pilot compensation was considerable but not really excessive. Had some objectionable deficiency in the flight control system.

TABLE B-6. (CONTINUED)

Runs 317-319; Conf. 1H; HQR 5:
Had adequate performance throughout the runs. Felt that it required considerable pilot compensation. And, if I had to pick an axis I felt caused more compensation or workload than the other, I'd say it was the pitch. The roll seemed to be pretty good, but the pitch seemed to have a whole lot of damping that caused me to work harder at that.

Runs 320-321; Conf. 6H; HQR 6:
Adequate performance is what I thought I had all the time. I required extensive or maximum pilot compensation to maintain that, primarily the pitch axis caused the most problem. Roll was not that good either.

Runs 322-324; Conf. 4H; HQR 5:
I felt like I could really only sustain adequate performance but a large percent of the time I did have desired. But, overall it would be adequate. Considerable compensation on my part to maintain adequate.

Runs 325-326; Conf. 6C; HQR 7:
I didn't see or feel that control was a problem, control of the airplane. But definitely major deficiencies in the flying qualities of the system there. I did feel like I did not get adequate performance all the time. Pretty much the maximum compensation I could put into it to try and keep it there.

Runs 326A; Conf. T6; HQR 4:
[No comments recorded.]

Runs 327-328; Conf. 1T6; HQR 6:
Felt like I had adequate performance all the time, although sometimes it was kind of close. Extensive compensation because I wasn't just able to look at it and use peripheral to watch the little throttle pointer. Tried to match that so I had to constantly look back and forth.

Runs 329-330; Conf. 6T6; HQR 6:
I felt like I had adequate performance on both tasks all the time. Required extensive pilot compensation on my part. The pitch seemed to give me the most trouble as far as workload.

Runs 331-332; Conf. HT6; HQR 5:
I really only got adequate performance throughout. There was one spurious input on the throttle where I went the wrong way, drove it down. But that was a mental error on my part. Just, adequate performance throughout. Considerable pilot compensation. The roll task required the most concentration, compensation on my part.

TABLE B-6. (CONTINUED)

Runs 333-334; Conf. CT6; HQR 5:
Felt that I had adequate performance only on the task. Required considerable compensation on my part.

Runs 335-336; Conf. 1HT6; HQR 6:
Felt like I had adequate performance all the time on all the tasks but required extensive to maximum compensation, almost to the limit of what I could do to maintain the adequate. Not an easy task.

Date: 24 Feb. 1989; Pilot B

Runs 341-342; Conf. 1; HQR 2:
Performance was satisfactory. Did require some pilot attention but pilot compensation was not a factor.

Runs 343-344; Conf. 2; HQR 3:
Performance was satisfactory. However, it did have some unpleasant characteristics in that there is a short term mode that requires some minor pilot compensation to avoid exciting to keep it in the satisfactory range.

Runs 345-346; Conf. 4; HQR 3-1/2:
Satisfactory performance was possible for the majority of the time. However, there were a significant number of excursions into the desired or adequate only level as a very annoying characteristic of exciting the pitch mode. It did require a bit of pilot compensation to maintain it within the satisfactory level.

Runs 347-348; Conf. A; HQR 2:
Able to achieve satisfactory performance with minimal pilot compensation.

Runs 349-350; Conf. C; HQR 4-1/2:
I was able to maintain adequate but not satisfactory performance. There are some moderately objectionable deficiencies that did require a moderate level of pilot compensation. Wouldn't say that the compensation required was considerable.

Runs 351-352; Conf. H; HQR 3:
I was able to achieve satisfactory performance but did require a little bit higher than normal workload to do that.

Runs 353-354; Conf. 2A; HQR 3:
I was able to obtain satisfactory performance the majority of the time. And primarily extra effort in the roll axis.

TABLE B-6. (CONTINUED)

Runs 355-357; Conf. 1C; HQR 5-1/2:
I was only able to maintain adequate performance with these. Major deficiency in the roll rate damping. Considerable pilot compensation was required for that, forced me to back off on the pitch task.

Runs 358-360; Conf. 4A; HQR 4-1/2:
I was able to obtain adequate performance, very nearly satisfactory but not quite. Had some minor deficiencies and it did take a fair amount of effort to maintain performance.

Runs 361-362; Conf. 1H; HQR 5:
I was able to maintain adequate performance. Does have some objectionable deficiencies in the lack of damping in the roll axis and again caused me to back off in the pitch task. Required considerable pilot compensation.

<u>Date: 24 Feb. 1989; Pilot V</u>

Runs 381-383; Conf. 2; HQR 2:
It's very predictable for small tracking, large tracking you tend to undershoot just slightly, you'll stop it just a little too early, but very little, essentially no compensation really required.

Runs 384-385; Conf. 4; HQR 4:
This one needs some minor improvement. When you made a reverse on force, it acted like a spring, it snapped out at you. And, if you had to go a long distance, you really had to apply a lot of force until you got there. But when it reversed directions, it was really snappy. So you had to apply some compensation there. Needs some improvement.

Runs 386-387; Conf. 5; HQR 6:
This mode definitely needs some improvement, very objectionable but tolerable deficiencies. Fine tracking was fairly good and initial response after a reversal force was good, and then it seems like about a third of a second into the reversal, you get this great change in direction, very oscillatory, lightly damped. The initial acquisition became very difficult.

Runs 388-389; Conf. A; HQR 1:
That one is excellent. It tracks very well. No problems, very predictable.

Runs 390-391; Conf. H; HQR 3:
This mode is good without improvements. Rate it a fair. Some mildly unpleasant deficiencies. Did require some compensation. You needed to really input before you got to it and try to control it. It had good fine tracking. A little bit of overshoot tendency in gross acquisition.

TABLE B-6. (CONTINUED)

Runs 392-393; Conf. B; HQR 6:
That mode definitely needed improvement and required a fair amount of pilot compensation. You put an input in and you had to lead it with, many times, a very sharp opposite force. I'd say it's very objectionable with tolerable deficiencies. Took extensive pilot compensation.

Runs 394-395; Conf. 2A; HQR 3:
Fairly good for control. A little added difficulty with two tasks over one. I'd say minimal pilot compensation required for desired performance. There wasn't anything too nasty there.

Runs 396-397; Conf. 5A; HQR 5:
This one definitely needed improvement. It was almost like you had to add some lag, you had to be very conservative when you reversed your force direction, not to reverse too much, because it really took off and wanted to overshoot it. I'd say the roll axis was very good. It was all in pitch that the problems existed. It was very lightly damped also. And adequate performance required considerable pilot compensation.

Runs 398-399; Conf. 5B; HQR 8:
This one was not adequate with tolerable pilot workload so it's Level 3. And, it really was very PIO prone both in roll and in pitch. The light damping in pitch caused you to really over control when you were trying to control pitch. Controllability in pitch was an issue.

Run 400; Conf. T6; HQR 1:
I think that was just fine. No problem, just throttle alone.

Runs 401-403; Conf. 1T6; HQR 5:
Could not quite get satisfactory performance, so I'd say it's in Level 2. Minor but annoying deficiencies. It was really difficult at times just to catch the pitch, which caused a little degradation in the throttle control.

Runs 404-405; Conf. 4T6; HQR 5:
This one needs some improvement too ... This one seemed moderately objectionable also. Dual axis took considerable compensation. Had a little bit of trouble in controlling pitch. It tended to want to overshoot just a bit.

Runs 406-407; Conf. AT6; HQR 2:
That one needed no improvement. Good, negligible deficiencies. Really found it paid off if you fly looking at the left side of the roll display, because your eyes are really close to the throttle display. There weren't any kind of problems, a minor amount of compensation.

TABLE B-6. (CONTINUED)

Runs 408-409; Conf. BT6; HQR 6:
That one definitely needed improvement. Had objectionable deficiencies, needed a considerable lead compensation in roll and I'd say adequate performance requires extensive pilot compensation.

Runs 410-411; Conf. HT6; HQR 3:
That one was satisfactory without improvement. There were some mildly unpleasant deficiencies. You tended to be real tied in the loop, it tended to give you more problems. If you backed off just slightly, it controlled very nice, such as to neutralize the control if you allowed the force on your hand to be real light to neutralize. If you were really tight, you almost always overshot. Not sure what caused that but that's how it was.

Runs 412-413; Conf. 2BT6; HQR 7:
On that one, adequate performance was not attainable with tolerable pilot workload. It had major deficiencies. Controllability was not a question, it just took considerable lead compensation in roll and pitch didn't seem overly predictable.

Runs 414-415; Conf. 5AT6; HQR 8:
Definitely was not adequate performance attainable with tolerable pilot workload, and it required considerable pilot compensation just to maintain control. This is in pitch. Roll was extremely positive. Pitch initial response very unpredictable and then it was heavy. It seemed very sensitive and light on initial control, then heavy after until you reversed again. And, it was very lightly damped, tended to oscillate or ring for quite some time. And pitch was very PIO prone, too.

Runs 416-417; Conf. 2HT6; HQR 4:
It needs some improvement but it wasn't bad. It was mostly the compounding of the three tasks that had the most difficulty. It was right between desired and adequate. Minor but annoying deficiencies.

Runs 418-419; Conf. 5BT6; HQR 10:
I'll give this one a clearcut 10. Improvement mandatory. I doubt this one, you could do anything with. You are definitely along for the ride. Very PIO prone in both axes and extremely light damping. Very little predictability and, in the response, direction was questionable.

TABLE B-6. (CONTINUED)

RUN NO.	PILOT	CONF.	HQR	COMMENTS
430-431	M	1	2	No overshoots. Easy to fly, almost no compensation.
432-433		2	3	Less precise, mildly unpleasant.
434-435		5	5	Low damping is obvious. Moderate compensation required.
436-438		4	3-1/2	Lack of precision.
439-440		6	6	Highly PIO prone, easy to excite low damping.
441-442		H	2	No obvious deficiencies. Compensation not a factor.
443-444		B	3	Noticeable lack of damping, a lot of compensation required.
445-446		C	6	Almost chase the forcing function too hard. Lack of damping very noticeable.
447-448		1	2	[No comments recorded.]
449-451		14	4	Very abrupt, high frequency bucking. Task performance -- HQR = 2 ignoring dynamics.
452-453		15	4	Neglecting ride quality task is a 2.

TABLE B-6. (CONTINUED)

Date: 13 March 1989; Pilot M

Runs 454-455; Conf. H; HQR 1:
No problems whatsoever performing the task. It's easily satisfactory without improvement. No obvious deficiencies. In fact, boy, I mean there, no pilot compensation involved. Trivial to fly and the task seemed really easy.

Runs 456-457; Conf. B; HQR 4:
This configuration clearly has a lack of roll damping. It's very obvious. It doesn't strongly interfere with the ability to perform the task, in fact, I can get desired performance most of the time. It's just a little bit, you have to be very careful about it, a lot of workload involved because you can't just put in a single slight input and chase the forcing function. If you do that, it'll pick up a lot of roll acceleration and it's hell trying to catch it. So, you tend to have to fly a doublet input, you have to put the input in and immediately take a little bit out, or you reverse a little bit. And that's a lot of workload, relatively. And so, it's just on the verge of being satisfactory without improvement. I think that a little bit of extra workload puts it into the Level 2 region. And, it's a minor but annoying deficiency and I'd say, I got desired performance but required moderate pilot compensation.

Runs 458-459; Conf. F; HQR 4:
Configuration is a little bit sluggish initially. Sensitivity is kind of a compromise between getting some initial response and over-driving the thing or large inputs. It's right on the edge of being satisfactory without improvement. The little bit of sluggishness causes somewhat of a tendency to chase the forcing function more than I would like. I know that I can do better than that. And so, there's a lot of compensation involved trying to get really good performance. I can get desired performance, so that's not a problem. But trying to get the errors reduced as well as I can is really tough. So I think I'm going to put it in the Level 2 region, but just say that it is a minor but annoying deficiency.

Runs 460-461; Conf. G; HQR 2:
No obvious deficiencies with the configuration. There's no bad characteristics. It seems to have good roll damping. Pretty good response, it's not extremely crisp and precise. I know what K/S looks like. This doesn't look like that. But, still very good and I'd say, pilot compensation is really not a factor for desired performance.

Run 462-464; Conf. 1A; HQR 3:
Nothing obviously wrong with either axis. Both pitch and roll are quite sharp. In fact, it took a little time to try to settle in on some sensitivities because control harmony can become real obvious,

or disharmony, if you have it abrupt in one axis, or a very high sensitivity in one, low in the other. But, otherwise, there's nothing, no really unpleasant deficiencies and I think that there's just a lot of work involved. Tough to track both axes at once. And, I still got desired performance.

Runs 465-466; Conf. 2H; HQR 3:
No obvious deficiencies in either axis in this configuration. Pitch is a little bit tougher than roll, a little harder to be precise. But still, I could get desired performance. Every once in a while it would go shooting outside the desired range, it's very easy to get back. No real problems in performing the task. Minimal pilot compensation required.

Runs 467-468; Conf. 2B; HQR 5:
This configuration had some deficiencies in both pitch and roll. The pitch deficiency was not strong. It was a lack of crispness, or preciseness, predictability. Roll was very sluggish, very low time constant or high delay or something. Difficult to be very precise in roll. In fact, the roll really kind of drove the configuration. I never felt like I was really getting good performance out of the roll axis. Deficiencies do warrant improvement. I was still getting adequate performance. I think the deficiencies were moderate.

Runs 469-470; Conf. 2H; HQR 2:
First run where we tried leaving the pitch axis free while driving only the roll axis. And, when the run first started, it took me a second to realize that. I started trying to track pitch, of course, chased it myself, and then through the first run realized that I didn't have to make any pitch inputs. But, if I still tried to keep the pitch axis, the error zero, it's a little bit of work because every once in a while you just accidentally cross-control anyway, you have no choice but to try to zero it. The instruction is to keep the arrow error at zero. But, as far as performing the primary task in this case, which is roll, not that bothersome. I think I was able to do a pretty good job. No obvious problems with this configuration. Not really any pilot compensation. A tiny bit more work, realizing first that you don't have to fly pitch, and secondly, keeping the pitch attitude level, keeping the nose level.

Runs 471-472; Conf. 2C; HQR 7:
Configuration had much worse roll characteristics than pitch. Pitch was almost second nature, which was a good thing, since roll was a real Delta Sierra. I mean, roll really was bad news. It is not, I got adequate performance. Was it attainable with a tolerable pilot workload? No. And I think the major deficiency is in roll, it's simply not attainable. It's attainable, I got adequate but not with tolerable pilot workload.

TABLE B-6. (CONTINUED)

Runs 473-475; Conf. 5H; HQR 6:
Another pitch/roll case and I ran it three times because, trying to sort it all out, there's very low damping in pitch and a little bit of a lack of damping in roll, lack of really crisp response in roll. But, in fact, doing steps and pulses to check the sensitivity, it seemed like it was going to be an un-doable task. But it really wasn't that tough. Adequate performance was attainable with tolerable pilot workload, but barely. It's not satisfactory without improvement. And I think the deficiency in pitch is very objectionable. I could fly through it, but it's not a fun ride.

Runs 476-477; Conf. 5B; HQR 6:
This is a really tough configuration to get desired performance out of because pitch is extremely lightly damped, bounces all over the place, and very abrupt, and the roll is very sluggish, no roll damping. So the roll tends to kind of wallow along like jello while the pitch really bounces. I think adequate performance is attainable with a tolerable pilot workload. It's a lot of work, but it's still tolerable. And it's not satisfactory without improvement. The roll is too sluggish, and the pitch is too lightly damped, but I can get adequate performance.

Runs 478-479; Conf. 5H; HQR 5:
This was a pitch/roll with the roll axis free, no forcing function on roll. Pitch was very lightly damped. Roll, it seemed easy, in fact, the characteristic of the stick seems easier to fly pitch alone without putting any cross-inputs than roll alone. Because there's a tendency when you're putting in lateral inputs to just move the stick a little bit and get some pitch contamination. Seems easier, also, to try to keep the wing level, it seems like a more natural combination. As far as the task itself, the configuration is not satisfactory without improvement, though I did get desired performance. It's the low damping. It's just moderately objectionable.

Runs 480-481; Conf. 5C; HQR 7:
This configuration had very low damping in pitch and roll. Very wallowy in roll. Initial response in pitch is abrupt and then the high-frequency mode was very low damped. So, an annoying ride in pitch and a lot of work to keep the error bar from getting away from me. Is adequate performance attainable with tolerable pilot workload? That's marginal. I definitely got adequate performance, I got desired most of the time. But, I think I have to say deficiencies warrant improvement. Neither one of them is alone the bad thing, but I think the combination is just unacceptable. The roll takes a lot of work to keep it under control and the pitch is just an annoyance. I can say it has major deficiencies. I don't think controllability was at all in question.

TABLE B-6. (CONTINUED)

Runs 482-485; Conf. 6H; HQR 5:

Trying different sensitivities in pitch. Sensitivity on that one started out a little bit heavy and worked toward a better compromise. It was a compromise to pitch because pitch was extremely lightly damped, very easy to excite the lightly damped mode. There's very little damping in roll as well. They're both a little tough to fly. The roll is definitely easier than pitch in this case. Roll just makes an annoyance. Adequate performance was attainable with tolerable pilot workload although in pitch, the ride is very annoying, very objectionable. So it is not satisfactory without improvement. I think it was a moderately objectionable deficiency, that was the pitch damping ratio primarily, that was the objectionable deficiency.

Runs 486-487; Conf. 6B; HQR 7:

Like most of the cases I've been flying, it's got really low damping in roll, like no damping in roll. Very low damping ratio on pitch, very oscillatory in pitch, very wallowy in roll. I was getting adequate performance but, boy, I was on the boundaries of it in both pitch and roll. And, so, while it was adequate performance, I don't think it was a tolerable pilot workload to keep both axes under control. There was never really lots of concern about controllability, that is, I never felt I was going to lose control, but it was not easy to keep it even close to the desired boundaries. And, I wasn't always sure it was going to continue within the adequate boundaries. And, in fact, if this were a realistic task, if this thing were to keep on going one way or another, I think I probably could lose control of the thing trying to chase it.

Runs 488-489; Conf. 4H; HQR 4:

This was on the edge of being satisfactory without improvement, neither axis having obvious deficiencies. There was a lack of crispness, or preciseness in pitch, lack of precision. A little bit of a lack of precision in roll, but it's more noticeable in pitch. I think it's on the verge of being satisfactory without improvement. I think it is just, it's a lot of work, so I think it's not satisfactory without improvement but there's no obvious deficiency of the aircraft. But, desired performance does require pilot compensation. It took a lot of work to keep the aircraft, to keep the error bar within the desired performance bound.

Date: 14 March 1989; Pilot M

Runs 490-491; Conf. 2; HQR 2:

The overshoot in that configuration is pretty obvious when I'm just doing the sensitivity check. But it's not nearly as obvious when I'm flying it. There's a little bit of a lack of precision in that

configuration but it's not really bothersome to do the task. It is satisfactory without improvement. Desired performance was attained at all times. I consider that a negligible deficiency, a little bit of a lack of crispness, or preciseness in the response. Actually, preciseness is very crisp, almost too crisp, but very precise.

Runs 492-493; Conf. 5; HQR 5:
This configuration clearly has very low damping. The low damping really doesn't cause any major problems in tracking. I'd say adequate performance is attainable with a tolerable pilot workload but it's not satisfactory without improvement because of that very low damping. It's annoying when you're trying to do the task, that you can excite this, in fact, most of the time it seems like you can do a pretty good job of tracking the pitch bar, and all of a sudden you'll excite that little low damped mode and go bucking and shuffling along. And it's enough to be just two or three times per run. The accelerations are large enough to call it moderately objectionable.

Runs 494-495; Conf. 4; HQR 4:
This configuration again has some overshoot. I'd say I got desired performance but I'm not sure it's really satisfactory without improvement. I couldn't get much precision out of it. In fact, I bounced between the edges of desired, plus or minus two and a half degrees. Sometimes out of desired. I could get it right back in the desired range but to really work hard on the second run and try to keep it within desired, I think was a lot of work. And so, although I don't think it's the overshoot problem, it's still not perfect and I'm going to say there was a minor deficiency but still enough to put it into the Level 2 range.

Runs 496-497; Conf. H; HQR 2:
First roll configuration and, boy, just no real obvious problems with this configuration. It's easy to fly, easy to keep the errors low. I think it's just a little too much response, a little too much command maybe, to always keep it within desired performance. I think maybe it could be a little bit sharper, crisper for response, not sure I need any more.

Runs 498-499; Conf. B; HQR 4:
Roll configuration clearly has a lack of damping. And, in fact, if you learn how to fly the thing, it requires an input to get the rate you need, and then a reversing input to stop it because it's almost like an acceleration response because of its lack of damping. But, it's really not too bad. I still got adequate performance, I really got the edge of desired performance. But I don't think it's satisfactory without improvement as a result of the low damping. I think that's a minor deficiency, and I think it required moderate compensation to get pilot desired performance.

TABLE B-6. (CONTINUED)

Runs 500-501; Conf. T1; HQR 2:
First throttle run and this is one of the new position throttle cases. It's very jumpy looking when you put an input in and, in fact, of the two runs, got two different sensitivities. The first one required too much control throw to do this relatively small input task. And the second one, with a more reasonable control throw, causes the error pointer to kind of look very jumpy. I prefer that as a compromise, realize that the pointer is going to do that. But, as a result, the whole system is not that great. It's easy to do the task. I think that that little bit of jumpiness in the error pointer is a deficiency, but this time a negligible deficiency. We'll see what happens when I go multi-axis.

Run 502; Conf. T2; HQR 1:
Just a piece of cake. It's satisfactory without improvement. No problems tracking the error. Good displacement. Good characteristics overall, I'd that it was highly desirable.

Run 503; Conf. T6; HQR 1:
No difficulty with the sensitivity, no problems with doing the task. With most of the throttle cases alone, there's just nothing obviously wrong with it. You have to make a pretty good amount of inputs on the throttle, but they're small, and they're not high-frequency. And just no compensation involved.

Runs 504-506; Conf. 2H; HQR 4:
No obvious deficiencies in either pitch or roll in this case. Everything looks pretty good, especially doing step inputs for setting sensitivities. Everything looks fine. But the combination is just a lot of work. It's trying to do the pitch and roll, and keep the aircraft in the desirable boundaries. I'm on the edge of desired, pitch and roll, almost all the time and having to pay a lot of attention to it. So, that's not satisfactory without improvement. And I think it's a moderate amount of pilot compensation even though I'm getting desired performance.

Runs 507-508; Conf. 2B; HQR 5:
Not as easy to fly as the previous one. There's no obvious problem with it. The roll seems to take a little more concentration, therefore, compensation. As a result, the pitch is a little sloppier. But it's not obvious that the pitch is any worse, just a little sloppier. So, both pitch and roll are pretty often outside desired performance bounds. So it's not satisfactory without improvement. While I know that the roll has low damping, it's not so obvious when I'm doing the tracking. It's just noticeable that it's a lot of work. It's a little sluggish. So, overall I'm going to say that adequate performance required considerable compensation.

TABLE B-6. (CONTINUED)

Runs 509-510; Conf. 5H; HQR 5-1/2:
Clearly has low damping in pitch. Roll, there's nothing obvious. In fact, roll is quite precise, quite easy to control, which is good because it allows me more time to concentrate on pitch. I could still get desired performance out of it, even though it's low damped and a very major annoyance as far as I'm concerned is the low damping. So, it's adequate but it's not satisfactory without improvement. And, so it's in Level 2 range. So the whole question is whether it's moderately or very objectionable damping. And I think, for this task, well, somewhere between the two, between moderate and very objectionable. So since I can't really decide.

Runs 511-512; Conf 5B; HQR 7:
This configuration has low damping in both pitch and roll, very obvious, very annoying. I got adequate performance, in fact, I got close to desired, but it's on the edge. It's a tough one to call, whether it's really Level 2 or Level 3 because the question is whether it's tolerable pilot workload. And I think that it's a lot of work but there's just enough times, there were a couple of times per run, where I'm not sure I'm gonna keep the thing under really good control, solid control in both pitch and roll. I'll focus on one axis and the other one gets away from me. I think it's just enough to push it into the deficiencies require improvement, or Level 3 area, because of the pilot compensation involved.

Runs 513-515; Conf. 2T1; HQR 3:
Both pitch and throttle had very good characteristics, no obvious deficiencies whatsoever in either response. It's a lot of work doing both and the nice thing about this pitch is that it seems so benign, I could actually dare to glance over and see what the throttle was doing. Usually I have to kind of fly just kind of being aware of whether the throttle pointer is running away from me or not, and respond to it. In this case, I didn't have to do that, so, I could actually take a little time to see what was going on with the throttle. There's a lot of workload, but it wasn't that difficult to get, I think, desired performance. So I think that was satisfactory without improvement.

Runs 516-517; Conf. 4T1; HQR 4:
The throttle is definitely a little too abrupt, a little too jumpy. I'm trying to watch the error pointer out of the corner of my eye, and it's hard to know whether it's going to take off on me or just move a little bit when I move the throttle. But sensitivity is a compromise between getting that and getting any response. In fact, at one time in the run I had the throttle full back, power off and barely was holding the desired, holding it at zero error. So throttle sensitivity is a compromise between getting any response at all and getting too much. Trying to not weigh hitting the stop on the throttle and just looking at the performance, pitch was a little

bit tougher and throttle was a little bit tougher. They're both a little hard together in this case. It's not satisfactory without improvement. I was on the edge of desired or outside desired considerably and I think deficiencies warrant improvement. On Level 2, it's just a question of whether I can call it desired performance or adequate performance because there's no major deficiency that I can see other than the little bit of abruptness in the throttle.

Runs 518-519; Conf. 2T6; HQR 3:
The difference in the throttle is obvious in this case, that is, I know I've got to put in doublets, it's almost like there's no speed damping, and that if I've got an input, I've got to take it out. But it's really not bad. In fact, this throttle has the advantage that the amount of throttle I get is directly proportional to the amount of response I get. And pitch is a piece of cake. And it actually is decently easy to fly. I could get desired performance. I think overall, you know, it's a lot of workload but it's satisfactory without improvement. I could do this task for a little while. I think, other than the fact that I know I gotta put in throttle doublets, there's no real compensation involved.

Runs 520-521; Conf. 5T1; HQR 5:
The pitch configuration was low-damped, the throttle is kind of abrupt, so they both tend to be a little abrupt. But the throttle is just sort of a little minor nuisance on top of the low damping, which is a major nuisance. And, most of the time I could get desired performance. But it's not satisfactory without improvement, again because of the damping. I don't think the throttle causes any major amount of difficulty other than distracting me a little bit. But, boy, with the thing bouncing around, I can't tell much difference, throttle or no throttle. So, I'd say it's a moderately objectionable amount of, lack of damping.

Runs 522-523; Conf. 2T2; HQR 3:
Either that was all very good or I'm getting better at this. No obvious deficiencies in either pitch or throttle in that case. Throttle maybe had a little tendency to run away on me but, doing the closed loop tracking I couldn't tell. So no difficulty. Pitch, no difficulty. In fact, I could spend my time still getting desired, almost at the edge of desired, splitting my time between looking over at the throttle pointer and back over at the pitch pointer, pitch bar, and had no real difficulty dividing my time between the two consciously. And so, I think it's satisfactory without improvement, a lot of workload still involved doing it.

Runs 524-525; Conf. 5T2; HQR 5:
Pitch was low damped, throttle was kind of an acceleration response, and the combination was a little annoying but throttle again was more of a nuisance on top of watching the pitch bounce around, and the

whole thing kind of buck and shake. So I think adequate performance is attainable with tolerable pilot workload. In fact, desired performance is attainable but it's a moderate objection again, primarily the pitch throttle caused the workload to be a little higher.

Runs 526-527; Conf. 5T6; HQR 5:
The low damp case is the same problem as the last series, or looks like it to me anyway. And the throttle doesn't look significantly different. I can't see any big differences between throttles because it's such a low frequency task, such a benign task by comparison that it just makes the workload up and the only difference maybe is that I'm getting used to the damping, or for some reason that seemed a little easier to fly than the last one. But, it's still got the low damping. It's not satisfactory without improvement because of low damping in pitch, throttle was not a major difficulty. I think it was a moderately objectionable deficiency.

Runs 528-529; Conf. HT2; HQR 4:
It's kind of an unnatural task in a way because one is predominantly longitudinal, one is lateral. But doing the task itself was not all that difficult, especially. It takes a little bit of work, a little bit of practice. I tended to watch the right side of the roll ball, the roll circle. If you watch the left side, you can actually focus in on an area where you see the error pointer and the bank angle error, all within a couple degrees of each other. It really makes it a lot easier to do the task once you learn how to do that and judge it properly. So, from that standpoint, it's relatively easy to do but still quite a bit of work. And this is almost desired performance, I got out of desired accidentally, trying to adjust my technique on the second run. But, I think overall, it was not too difficult to do.

Runs 530-531; Conf. BT1; HQR 4:
Roll was a little bit sluggish, lack of damping in roll, noticeable lack of damping in roll. But the task is still do-able. In fact, again the throttle is just a little bit of an annoyance and not a major one at that. Actually, roll throttle, once you learn how to fly it and how to look at the display, is not all that difficult. I think I got desired performance most of the time, maybe not all of the time, but, I think, enough that I could get desired in both roll and throttle. Enough that I'm going to say that while it's not satisfactory without improvement, it's only got minor, but annoying deficiencies, and that's the lack of damping in roll.

Runs 532-533; Conf. BT6; HQR 4:
This configuration has not really super crisp roll damping but it's not too bad. In fact, the task is do-able. I think I'm on the edge of desired performance in roll all the time. Throttle is again just

kind of an annoyance, it's there. I think it's not satisfactory without improvement. It would be nice to have it a little sharper and the throttle a little easier. But, it's a minor deficiency.

Runs 534-535; Conf. HT1; HQR 3:
No obvious deficiencies in either throttle or roll in this case. It's a lot of work, as usual, together. Throttle is maybe a little jumpy but really not all that bad. It's easy to spot them since, you scan just one area and see both throttle and roll at one time. So it makes the task pretty easy, relatively easy. Make that satisfactory without improvement.

Runs 536-537; Conf. BT2; HQR 4:
This configuration, again, had a lack of roll damping. The throttle, you know there's different throttle configurations. I can't pick 'em out when I'm doing the task itself, but they're really not that different. The task is still benign. I think I gcc adequate performance with a tolerable pilot workload. I don't think it's satisfactory without improvement. The low roll damping being the problem, just a lot of work trying to keep it. I was on the edge of desired in roll, both ways, ± 15 degrees of error and that's just not acceptable to me for a Level 1 aircraft. So, I think I could get desired performance but, with a lot of workload.

Runs 538-540; Conf. 2HT1; HQR 4-1/2:
There's no single axis that's really bothersome. In fact, all three axes are quite well behaved. I have no difficulty doing any one of them. The combination is a real handful. I think I got adequate performance. I don't think I was in desired all the time. In fact, every axis, I was out at some point, outside the desired bounds without really picking it up immediately. Pitch and roll I would get under control, then I'd realize throttle was out, and so it's not satisfactory without improvement, primarily just a major amount of workload involved. And, as I said, it wasn't really in desired, but I wasn't always down in adequate.

Runs 541-542; Conf. 2HT6; HQR 4-1/2:
Like the last configuration, there's no obvious deficiency anywhere. A lot of pilot workload involved. I got adequate performance. I didn't get desired performance in all axes, at all times, just because workload is high and I couldn't keep it under control that well on all axes. So, it's not satisfactory without improvement. There are no obvious deficiencies, so it's more my performance measurement. And again, an HQR 4 says desired performance requires moderate compensation. HQR 5 says adequate performance requires considerable. I got adequate but it didn't require considerable.

TABLE B-6. (CONTINUED)

Runs 543-544; Conf. 2BT1; HQR 6:
I think I got adequate performance with this particular configuration. There's an obvious deficiency in roll, that's the roll damping and it really stands out when I get the three axes like this. Throttle is no problem. Pitch is no problem. But the combination with this very, very sluggish roll, makes it very tough to fly. I think here the disharmony between pitch and roll really shows up because pitch is very responsive, and roll is not. I think I tended to pull too much on pitch, sometimes when the roll banking was getting on. So the combination is really annoying. I got decent performance but I think the pilot compensation was what I'd call in the extensive range.

Runs 545-546; Conf. 4HT1; HQR 4:
There's no obvious deficiencies in any axis again in this case. The throttle is one of the position throttles, but when you're flying, you really don't know it except it takes full throw sometimes to get the errors in control. But that's really not much of an annoyance. I don't think it's satisfactory without improvement because of the workload involved. And I'm sort of stuck here at the 4 and a half level again for an HQR. But I think this one seemed a little easier. Maybe I'm just getting used to flying this.

Runs 547-548; Conf. 2BT6; HQR 5:
This configuration had low roll damping. Pitch seems fine. Throttle seems fine. Not satisfactory without improvement. I got adequate performance. In fact, I got pretty darned close to desired in pitch and throttle. I got out of desired in both when I was chasing the roll. And, as a result, I don't think it was all that terrible to fly, that low damping is moderately objectionable. I think it took a lot of compensation.

Runs 549-551; Conf. 5HT6; HQR 6:
This one is low-damped in pitch, fortunately very good in roll, and good in throttle. 'cause, with the low damping in pitch, it's so annoying that you spend a lot of time kind of chasing the pitch bar. And so, you tend to get the banking a little off and tend to get the throttle off a little bit. But, they're not that hard to make up. And I do get adequate performance with a tolerable pilot workload, barely. It's not satisfactory without improvement. I think the low damping and the combination of all the high workload makes it almost in the region of not being tolerable.

Runs 552-554; Conf. 5HT1; HQR 6:
Throttle was a little bit abrupt, seemed too snappy, unreal, but not a big deal. Again I had to bring the throttle full aft at one point. The biggest problem with this configuration was pitch, just low damping in pitch. It would really go bucking around when I was trying to track in pitch. Roll was not all that difficult. But the

combination is still a lot of work. It's not satisfactory without improvement. I think the pitch damping is maybe the moderately objectionable realm. But the combination of the three requires more workload than I think is really acceptable.

Date: 15 March 1989; Pilot H

Runs 555-556; Conf. 1; HQR 2:
That's satisfactory without improvement. Just negligible deficiencies, pilot compensation really isn't a factor, you just have to work because obviously the display is pretty active. So, it's not a 1 because I do have to do something. But dynamics are excellent.

Runs 557-558; Conf. 2; HQR 2:
That was satisfactory without improvement. Was able to get desired performance. Stick sensitivity was fine. So it would be negligible deficiencies.

Runs 559-561; Conf. 4; HQR 4:
That one is actually not satisfactory without improvement. It's got some minor deficiencies which warrant improvement. The main symptom there is the tendency to pitch bobble. And the other problem is that, when the disturbance pushes it off the display, it seems to go off there faster, so I spend more time in the adequate region. And I'm not sure if that's a disturbance that I don't seem to be able to bring it back as quickly. That combined with the bobbling makes it not Level 1, it's just barely Level 2. So, it's minor but annoying deficiencies, and moderate pilot compensation to try to compensate for that pitch bobbling. We tried two sensitivities. The second sensitivity was definitely better.

Runs 562-563; Conf. 6; HQR 6:
That is a toss-up between deficiencies that require improvement and, those that warrant improvements. I could definitely get adequate performance. And the quandary is, that it's certainly a major deficiency with that high-frequency oscillation following every input. It is controllable for this task. I can keep the bar for this particular task inside the desired range, I'd say 80 percent of the time, and adequate the other 20 percent of the time. My technique was to definitely back away from it, not excite that high-frequency mode.

Runs 564-565; Conf. H; HQR 2:
That one is satisfactory without improvement. Negligible deficiencies. Pilot compensation not a factor.

Runs 566-567; Conf. B; HQR 3:
That one is satisfactory without improvement. It did have some

mildly unpleasant deficiencies, was a little bit sluggish. And my first impression was gonna be, excessively sluggish. But, doing the task, it was not that big a problem. Flew a little bit like a DC-10 or something. But for the disturbance that was in here, most of the time, 95 percent of the time, was in desired region, at 15 degrees of bank.

Runs 568-569; Conf. C; HQR 4:
First question, is it satisfactory without improvement? Answer is No. Deficiencies do warrant improvement but it's not really a significant deficiency. It's too sluggish but I could get desired performance from it most of the run. I'd say at least 95 percent of the run. Required, definitely, concentration to do that, but, so it falls under the heading of desired performance requires moderate pilot compensation.

Runs 570-571; Conf. 2H; HQR 3:
I'd better call that satisfactory without improvement. Although the workload is getting up there, it's close to saying it's the 4 range, just because you work real hard. And one thing I've noticed is that, unlike a flight director with a cross hair where you try to get the place where the hairs cross to the middle or the columns-type display, where it's a more integrated display, this display is not integrated so you have to share your attention between pitch and roll. And so the workload is higher than it would be, say on those more integrated type displays. That requires more division of attention. Then the last of the two, the dynamics in two axes is quite good.

Runs 572-573; Conf. 2B; HQR 5:
That is not satisfactory without improvement and deficiencies warrant improvement. The primary problem was, it's sluggish in roll. The pitch seemed OK but the roll axis is definitely too sluggish. The combination of the two together results in moderately objectionable deficiencies. The performance in pitch was probably desired but in roll, certainly only adequate.

Runs 574-575; Conf. 4H; HQR 3:
Satisfactory without improvement, the answer is Yes. It's marginal because of the task. The task is a tough one. And, because the display is not integrated, there's a lot of division of attention. But in that context, the dynamics are quite good actually. I think I kept it in the desirable range most of the time. If I had any problem, it was usually in pitch. But I still say that pilot compensation was minimal and satisfactory without improvement. Some marginal feeling about pitch axis.

Runs 576-577; Conf. 6H; HQR 7:
Is it controllable? Answer is Yes. Is adequate performance

attainable with a tolerable pilot workload? I think the answer there is No. I think the deficiencies require improvement as opposed to warrant improvement. They definitely require improvement. It's a major deficiency. The primary problem being the oscillatory mode in the pitch axis. Actually, my performance probably was adequate but I think the over-riding factor in the ratings, on the left side, that's a deficiency that requires improvement. Control was never an issue.

Runs 578-579; Conf. 4B; HQR 5-1/2:
Adequate performance attainable. Tolerable pilot workload, Yes, however it's not satisfactory without some improvement. Deficiencies warrant improvement. The primary problem being a very sluggish roll axis. And, with the roll axis being sluggish, that sort of degrades the performance as well. I'm really torn between a 5 and a 6 there. Somewhere between moderately and very objectionable. Performance was adequate. It was desirable pitch and adequate roll.

Runs 580-581; Conf. 4H; HQR 3:
That one is satisfactory without improvement with some qualifications. I'm gonna say that it's fair with mildly unpleasant deficiencies, minimal compensation, everything associated with HQR 3, but the caveat to that is that the workload is high. The dynamics are definitely good. I'm in the desirable range for, essentially, all the run, except working hard to do it. Lots of large motions and it's pretty intense. Nonetheless, based on the descriptors on the scale, the task here, I'd say it's satisfactory without improvement. I'm not sure how it could get any better with this particular set-up with this forcing function and so on.

Run 582; Conf. 2H; HQR 3:
We start out with a fairly demanding task. It is very much of a piloting type task, altitudes and finding checkpoints on the ground and headings and so there is considerable division of attention. You have to divide your attention between altitude control, finding the checkpoints on the ground and sometimes using headings so you feel more like a pilot than with most simulator tasks. In terms of the ratings for that configuration, Is it satisfactory without improvement? Yes, but not great. It should be more crisp in both pitch and roll, so I would say that it is fair with some mildly unpleasant deficiencies, just a bit sluggish not crisp in it's ability to nail down a bank angle, to nail down a pitch attitude. However, the desired performance was achievable. Desired means, if I can get my altitude within 50 or 75 feet.

TABLE B-6. (CONTINUED)

Runs 583-584; Conf. 4H; HQR 3:
That one is satisfactory without improvement. Desirable performance in most cases. The only time my performance was undesirable wasn't because of handling qualities, it was just because my instrument scan may not have been high enough where I went to the wrong altitude. However, flying quality wise, I was able to achieve whatever I was after mentally reasonably well, with the altitude within 50 feet. The roll axis was excellent, but the pitch axis still a little bit sluggish for really something that would be better than a three.

Runs 585-586; Conf. 6H; HQR 5-1/2:
That one is an excellent roll axis and a deficiency in the pitch axis which consisted of a high frequency lightly damp mode, but that mode appeared to be above the reach of what I really needed for good flight path control. So it was more of an annoyance in that it was a major factor in interfering with my ability to control flight path. The biggest problem with that mode is if you get behind the airplane and get aggressive that it gets excited and it causes a lot of vertical acceleration oscillation. In terms of pilot rating, adequate performance attainable with tolerable pilot workload. Deficiency warrants improvement. Oscillatory mode in pitch is the deficiency I am referring to. Somewhere between a moderately and very objectionable deficiency although I was able to get desirable performance. This is a mode that you would fail to as a Level 2 system if you had a primary system failure and you failed to this. You could easily get this airplane home and in effect continue the mission with some degraded performance. So in the true sense of Level 2, this would be in that region.

Runs 587-588; Conf. 2H; HQR 3:
Satisfactory without improvement. Basically no roll control variance so it's all pitch. However it's marginally in terms of being somewhat sluggish, I would prefer something more crisp. Therefore it's fair with a mildly unpleasant deficiency that being the somewhat sluggish pitch response.

Runs 589-590; Conf. 4A; HQR 3:
Satisfactory without improvements. Still a little bit sluggish in pitch. Not as crisp as you'd like it to be in pitch. Still definitely in the desirable range.

Runs 591-592; Conf. 6A; HQR 5:
That is the case with that high frequency lightly damped mode, which for the flight path control task doesn't get that excited unless I aggressively go after flight path due to getting behind the task. It's an annoying deficiency but I can do the task just fine, in fact it' actually kind of crisp but I think one or two times when I really went after it, it got some nasty flight path normal acceleration

oscillations. That is a moderately objectionable deficiency. Stabilizing-wise, in terms of having to do closed loop compensation to make the thing stable in pitch and path, that does not seem to be a factor. I'm operating well below that frequency, I didn't feel a need to tighten up to that frequency.

Runs 593-595; Conf. 1H; HQR 3:
That is primarily a role task and I'll have some words to say about the pitch part of the primary task. Satisfactory without improvement. The roll axis is negligible deficiencies. No problem at all as far rolling getting a precise roll angle and anything having to do with the lateral task. It is very difficult to disassociate the pitch part of this task in that the pitch attitude response is still a little sluggish and we have a digital altimeter and in that context I feel that the overall task is still a 3. So, HQR=3 for the overall task including altitude control and if I were to rate the roll axis separately it would be HQR=2.

Runs 596-598; Conf. 1B; HQR 5:
Adequate performance obtainable with tolerable pilot workload. Not satisfactory without improvement. The primary problem is it's sluggish in roll and difficult to get a really precise, crisp bank angle out of it, and in fact, a few times in rolling out on the runway, it got into a roll oscillation. Also, the attention required to achieve precise bank angle results in problems in the altitude control. Because of that sluggishness in roll I would rate it moderately objectionable, it requires considerable compensation and it doesn't leave time to look at anything else.

Runs 599-600; Conf. 1C; HQR 7:
Adequate performance with tolerable pilot workload, NO. The deficiency requires improvement, specifically referring to extremely sluggish roll response, and that combined with a moderately sluggish pitch response makes for a major deficiency. It is quite noticeable in especially lining up the runway, it is difficult to get a good lineup out of that offset condition. It is very difficult to capture a bank angle without overshooting and wallowing.

Runs 601-602; Conf. 2; HQR 2-1/2:
It is satisfactory without improvement. Performance was definitely within the desirable range over 90 percent of the time. Reasonably crisp response.

Runs 603-604; Conf. 14; HQR 2:
That was an attitude system. Its only problem was an enlarged disturbance amplitude. Sometimes I could only momentarily track it because the pitch attitude just didn't have enough authority. The

rest of the time, 99 percent of the time, the ability to track was excellent. It was very crisp, and there was no fear of overdriving the display, getting into a bobbling situation, so there was no need to back off and allow for any dynamics or time delay. So it was easy to be good and aggressive with it.

Runs 605-606; Conf. 15; HQR 3:
That attitude command was extremely crisp. Didn't really notice any tendency to bobble or any of the things that might show up in an attitude system. As long as it was in the region where I had control it centered the bar very nicely. Once or twice during the run I did go to on or near the stop momentarily (on the longitudinal stick), but in the overall context of the run that wasn't an issue, because it immediately became small again. Once in a while it hits the stops and it does require some large stick reflections to know the errors, but the dynamics are excellent.

Runs 607-608; Conf. 2C; HQR 6:
This deficiency certainly warrants improvement, primary problem is a very sluggish roll response. Trying to keep the roll under control causes some fairly large pitch excursions. The primary objection is in the roll response. Adequate performance requires extensive pilot compensation.

Runs 609-610; Conf. 6B; HQR 8:
Adequate performance attainable with tolerable pilot workload: NO. Deficiency definitely requires improvement. It is a major deficiency, that is, very sluggish in roll, and has a very lightly damped mode just above the frequency where you'd like to control it. Any attempt to catch up as you get behind the display excites that mode and that requires time to let things settle down and accept some fairly substantial errors. I consider that technique of having to back out of the loop and let it settle down and attempt to maintain control. I would say that considerable pilot compensation is required for control in that context.

Runs 611-612; Conf. 1A; HQR 2:
That one is definitely satisfactory without improvement. The roll was excellent, a one in roll. Pitch characteristics were also very good, very crisp pitch response, probably my best altitude response all day. There was more time for scanning, more time for paying attention to getting really good performance. Pitch had negligible deficiencies.

Runs 613-614; Conf. 5A; HQR 4-1/2:
Deficiencies satisfactory without improvement, NO. Deficiencies warrant improvement, and in particular it is the high frequency pitch mode that seems to follow any abrupt inputs. Very slow inputs don't excite that mode, but the response in pitch is quite crisp. The

ability to control the vector is reasonably good, until I try to put the pipper on a target, such as diving into that town there, then it's a bit difficult because the high frequency mode seems to make the pipper somewhat elusive. The deficiency is somewhere between minor but annoying and moderately objectionable.

Runs 615-616; Conf. 1A; HQR 2-1/2:
Satisfactory without improvement, absolutely yes. The roll is excellent in fact I'd give it a 1.5 for roll. For the most part I was able to control the altitude reasonably well, except I can't resist making some comments about that flight path, it was just about impossible to find a place to put it, to control, to put it where sink rate, climb rate, would be equal to zero. The biggest part of this task was trying to find a reasonable pitch attitude to hold $\dot{h}=0$. I'd don't think we should downrate the roll axis on that, because it is independent.

Date: 16 March 1989; Pilot H

Runs 617-618; Conf. 1; HQR 2:
Satisfactory without improvement, basically ideal dynamics. Good with negligible deficiencies.

Runs 619-620; Conf. 4; HQR 3:
Satisfactory without improvement, Yes but marginal. There is some mildly unpleasant deficiencies. There is a tendency to bobble the pitch attitude, especially after an aggressive input, in the random input in the HUD, if it is a large excursion, and an aggressive attempt to go after that results in some pitch bobbling. Otherwise it is pretty crisp, and pretty predictable. There is a tendency for pitch bobbling when you get real aggressive with it. Not a PIO, just leftover pitch bobble. The performance was in the desirable range, nearly all of the time. Compensation was minimal, you have to live with that little pitch bobble.

Runs 621-622; Conf. 5; HQR 5:
That one comes in under the heading of deficiencies warrant improvement. Definitely Level 2. The deficiencies I am referring to are those high frequency lightly damped oscillations. The frequency of that oscillation is a little beyond the frequency at which I'm doing all my tracking, but any aggressive stick inputs excite that mode, resulting in residual bobbling. I notice when doing the initial sensitivity runs that there is a tendency on top of that to drop back a little bit. The combination of those two things makes me unwilling to go after large errors in the display, and therefore there is only adequate tracking going on, I'd say only about 10 percent of the time its in the adequate region.

TABLE B-6. (CONTINUED)

Runs 623-624; Conf. H; HQR 2:
Those were definitely ideal dynamics. Satisfactory without improvement and negligible deficiencies, basically no deficiencies.

Runs 625-626; Conf. F; HQR 3:
Satisfactory without improvement, Level 1. Some mildly unpleasant deficiencies, in particular that being somewhat s[illegible] the roll axis.

Runs 627-628; Conf. C; HQR 4:
The noticeable problem with that configuration is somewhat sluggish roll response. In this case the deficiency warrants improvement. The performance seemed to be in the desired range most of the time, except for a few minor excursions, except for a large input, so it comes under the heading of a minor but annoying deficiency, moderate compensation to get desired performance.

Runs 629-630; Conf. G; HQR 2:
The response characteristics in roll on that one were pretty much ideal. I'd say that negligible deficiency.

Runs 631-632; Conf. 1H; HQR 3:
The dual task and workloads are pretty high, but the dynamics seemed pretty close to ideal. Getting pretty used to the display and the fine tracking is fairly natural. It seemed like the performance was in the desirable range nearly all the time. Satisfactory without improvement. That is in the context of a pretty high full concentration workload because of the task.

Runs 633-634; Conf. 4C; HQR 5:
The primary feature on that configuration was that it is pretty sluggish in roll. The combination of being sluggish in roll and a fairly demanding task, puts it in the deficiencies warrant improvement range, Level 2. Basically moderately objectionable, with a lot of roll excursions in the adequate range.

Runs 635-636; Conf. 5H; HQR 5:
The primary deficiency for that one is the high frequency lightly damped mode in pitch which makes it necessary to either fly it one of two ways. In the first run I flew it by backing off, avoiding exciting the lightly damped mode and just accepting some larger errors. In the second run I chose to be a little more aggressive than just flying, flew the pitch oscillations, either way it is pretty poor to fly. It comes under the heading deficiencies warrant improvement, moderately objectionable.

Runs 637-638; Conf. 5C; HQR 6:
The primary deficiencies on that configuration were a combined lightly damped mode in pitch at high frequency and a pretty sluggish

roll response. Nonetheless, I was able to maintain adequate performance certainly not desired, you had to back off and let it be adequate, I think the combination of those two results are very objectionable, deficiencies are tolerable. You can maintain adequate performance and do the job.

Runs 639-640; Conf. 1A; HQR 2:
Pitch control was excellent, it has ideal pitch. Good with negligible deficiencies. I was able to nail all the attitudes and altitudes reasonably well. In leveling off and setting up climb rates it is better to let the flight path do what it will. With that technique it is much easier to be precise.

Runs 641-642; Conf. 5A; HQR 4-1/2:
That configuration was the lightly damped mode at high frequency, interestingly it has a nice crisp pitch response, and a pretty good flight path response, except for the high frequency carrier on the top of the basic response. This is certainly an annoying feature and makes any very high frequency, very aggressive pitch tracking impossible. For this task it allows desirable performance, I'd have to classify it somewhere between minor but annoying and moderately objectionable. Certainly you wouldn't want that to be Level 1 with that oscillation in there.

Runs 643-644; Conf. 4A; HQR 1-1/2:
Those pitch dynamics were ideal, absolutely excellent pitch control, and as a result flight path control is also excellent, technique being to put the attitude where I want it, and the flight path vector would rapidly follow up and fall directly on the attitude. Pointing was excellent, altitude control was very good.

Runs 645-646; Conf. 1H; HQR 2:
The roll control on that slalom course was excellent. Satisfactory without improvement, in fact it was desirable.

Runs 647-648; Conf. 1C; HQR 6:
The primary problem with that configuration was that is has sluggish roll response. Definitely comes under the heading deficiencies warrant improvement. The big question that I had during the runs was whether or not I wanted to push it into a 7, which is deficiencies require improvement. I think all in all it is controllable, controllability is not an issue, as long as you really stay with it. That is excessive pilot compensation. In that context we will call it very objectionable but tolerable, acceptable being a failure mode, but it is at the bottom of a very marginally acceptable. The primary problem with that configuration is a tendency to be continually in a small low frequency roll oscillation, that is achieving a steady bank angle results in a small oscillation and then

TABLE B-6. (CONTINUED)

lining up with the runway I can feel a small oscillation, but it is controllable given some time.

Runs 649-650; Conf. 1F; HQR 4:
That one was pretty much characterized by marginal roll control. I'm torn between a Level 1 and Level 2. It is probably sluggish enough that it is a Level 2, it is characterized by its small oscillations after an aggressive roll capture, it comes under the heading minor but annoying deficiencies. Desired performance requires moderate compensation, you have to stay with it in roll. I noticed that on some occasions I didn't pay attention to roll and altitude drifted off some.

Runs 651-652; Conf. 2; HQR 2-1/2:
Satisfactory without improvement. Nice and crisp, pretty predictable attitude response. There might have been a slight tendency to pitch bobble when being aggressive due to somewhat of a dropback from pitch rate overshoot that we noticed during the sensitivity runs. That didn't seem to be much in the tracking.

Runs 653-654; Conf. 9; HQR 2:
The configuration had excellent pitch dynamics, crisp and very predictable. I was able to be very aggressive with it because I knew it would go right where I pointed it, so I was able to get after just about any error. I might have picked just a tad higher sensitivity so that I wouldn't have full stick trying to get some of the large errors.

Runs 655-656; Conf. 7; HQR 3:
The primary deficiency on that was the somewhat sluggish pitch axis. Although my performance was desirable most of the time, over 95% of the time. There was no tendency to PIO, and no pitch bobbling. Satisfactory without improvement, with a mildly unpleasant deficiency being a little sluggish.

Runs 657-658; Conf. 13; HQR 3:
Characterized by a fairly crisp pitch response with some dropback. However, that had very little effect on the tracking that I could perceive, with the exception of perhaps some small pitch bobbling at high frequencies. An example would be going after an aggressive disturbance input and finding myself actually overshooting it. Mildly unpleasant deficiencies.

Runs 659-660; Conf H; HQR 2:
Couldn't find anything wrong with it.

Runs 661-662; Conf. I; HQR 4:
Run had somewhat of an unusual response characteristic. It seemed to be quite crisp in terms of its time response, but there seemed to be

sort of a lag between when I put the input in and when it actually got going. I noticed that in the roll tracking, I tended to get a little larger errors, a little more bobbling around zero, because of always pulling over behind it. Minor but annoying deficiency.

Runs 663-664; Conf. 7H; HQR 4:
The primary problem with that one was the somewhat sluggish pitch axis. Although I have to say the roll axis was fine, the pitch axis was a little sluggish but quite predictable, as a result I could put in some very aggressive inputs, and not have to worry about bobbling. Because of the complexity of that task, of tracking two axes and having somewhat of a sluggish pitch control, it falls into Level 2, minor but annoying deficiencies. That deficiency being a little bit too sluggish for pitch control, a few excursions into the adequate range, but most of the time desired.

Runs 665-666; Conf. 9H; HQR 3:
That was a good configuration, nice and crisp for pitch and roll. Even with the very complex task it is still a Level 1. The only reason it is a three and not a two is it was a difficult task, and some compensation is required to handle the job.

Runs 667-668; Conf. 2I; HQR 4-1/2:
The problem was primarily in the roll axis. The pitch axis is Level 1. Roll axis felt like it had a time delay in it. As a result, there was a continuing oscillation and roll, requiring several reversals of the controls, but it wasn't that serious and we were in the desirable range most of the time. Somewhere between moderately annoying and moderately objectionable deficiency.

Runs 669-670; Conf. 13H; HQR 3:
Both axes were in the satisfactory without improvement range. With the workload being quite high because of the two axes tracking, definitely good dynamics, especially the pitch, was nice and crisp. In the beginning of the run, in the sensitivity checks, pitch rate overshoot or dropback, but that was not a factor in the tracking.

Runs 671-672; Conf. 2A; HQR 1-1/2:
That was a dolphin run with excellent flight path characteristics. The pitch was crisp and able to achieve a target altitude, flight path rapidly caught up to the pitch. Putting the flight path vector on a target on the ground was really quite simple.

Runs 673-674; Conf. 9A; HQR 1-1/2:
Pitch attitude characteristics and flight path characteristics were excellent. Couldn't really find anything wrong, the flight path follows the pitch and the pitch is as solid as a rock.

TABLE B-6. (CONTINUED)

Runs 675-676; Conf. 7A; HQR 3:
Characterized by a marginally sluggish pitch response. In terms of crisply getting to a pitch attitude, we're crisply putting the flight path vector on the ground target, to simulate a strafing run, it is marginal. Either a bad 3 or a good 4.

Runs 677-678; Conf. 13A; HQR 3:
Pitch control now is characterized by a nice crisp response for the little bit of a dropback and pitch rate overshoot. The result was a slight tendency to bobble. Mildly unpleasant deficiencies, with minimal pilot compensation to do the task.

Runs 679-680; Conf. 1; HQR 2:
Characterized by an excellent pitch response. The performance was all within the desired range.

Runs 681-682; Conf. 4; HQR 4:
That was an interesting run, characterized by a tendency to overshoot the pitch response, when faced with a large excursion in the command input. So I spent quite a bit of time within the adequate region although I was able to bring it back to desirable, there was quite a bit of excess motion display. Minor but anno[illegible]g deficiencies. I seem to miss the motion cues when I go after [illegible] bar, there should be something happening and it feels like nothi[illegible]is happening when I go after the bar, so I'm halfway missing the heave cues, pitch rate cues, I feel disconnected from the display.

Runs 683-684; Conf. 6; HQR 5-1/2.
That was one of those configurations, attempts to control it result in a lot of thrashing around there. Deficiencies definitely warrant improvement. There is quite a few larger excursions, on that basis I gave it a 5 and a half. I noticed a lack of heave or pitch cues, the airplane did not respond to my inputs, compared to what I've become used to.

Runs 685-686; Conf. A; HQR 2:
That is definitely satisfactory without improvement, an ideal response characteristic, we kept it in the desired range all of the time. I could be as aggressive as I want without contaminating oscillations or sluggishness.

Runs 687-688; Conf. H; HQR 3:
Characterized by a slightly sluggish roll response, but certainly nothing that is serious in terms of doing this task. Always seemed to be in desirable range. I missed the motion cues in roll a lot less than I missed them in pitch. I don't notice that much difference. Fair to mildly unpleasant deficiencies, that being the slightly sluggish roll response.

TABLE B-6. (CONTINUED)

Runs 689-690; Conf. C; HQR 5:
That was a roll only task, characterized by a very sluggish roll response. That showed up in the tracking with a lot of overshoots. There was a tendency to get into a PIO and certainly a deficiency that warrants improvement. Moderately objectionable.

Runs 691-692; Conf. C; HQR 3:
[Low forcing function bandwidth and amplitude.] That is a bit confusing one because it is quite sluggish, but I was in the desired range the whole time, because it looked like it would be disturbed. So in terms of doing the task, it is a HQR=3 for the task. I qualify that because it seemed to be excessively sluggish.

Runs 693-694; Conf. 1A; HQR 2:
There definitely seems to be a transition effect going from motion to no motion. At first it seemed that the pitch sensitivity is very low, when we took away the motion. Now I feel that I'm back to where I don't notice that the pitch is gone or low. I'm quite willing to forget the idea that this is airplane, to track it and be more aggressive. Good with negligible deficiencies.

Runs 695-696; Conf. 4H; HQR 5:
This configuration was somewhat confusing. First of all, in doing the sensitivity check I noticed that there was fairly crisp pitch response with some dropback or pitch rate overshoot. Roll response was quite good, and I expected it would be a Level 1 response. With fixed base I'm willing to be a lot more aggressive, there is a tendency to just be aggressive and that tends to excite this pitch rate overshoot or dropback which results in fairly large excursions well into the adequate range. The excursions are frequent causing the roll to get excited. I think I tend to excite that overshoot mode, significantly more without motion than I did with motion, if I'm seeing what I think I'm seeing. Moderately objectionable basically because of the thrashing around in pitch that occurred when I aggressively tried to keep things centered.

Runs 697-698; Conf. 6C; HQR 7-1/2:
Characterized by a lightly damped roll and pitch and sluggish roll response. I miss the motion cues in terms of trying to stabilize the somewhat undesirable configuration, definitely need some help there to tell you what is going on and sort things out. I see lots of thrashing around or rapid motions on the display. I need to sort it all out. Some spikes are beyond the adequate region. Definitely deficiencies require improvement. Bank angles look like 45 degrees or so.

Runs 699-700; Conf. 2H; HQR 4:
This one appeared to be very good, pitch and roll. During the runs I noticed that I couldn't keep the roll in the desired range, I kept getting roll excursions of 30 degrees and above. It seemed to occur

quite frequently, a lot of activity, thrashing around trying to keep things centered. Minor but annoying deficiencies, desired performance required moderate compensation.

Date: 17 March 1989; Pilot H

Runs 701-702; Conf. 1A; HQR 2 [Note: Pilot was excessively aggressive; not used in analysis]:

That is an excellent roll case ideal dynamics. Satisfactory without improvement.

Runs 703-704; Conf. 1G; HQR 4-1/2 [Note: Pilot was excessively aggressive; not used in analysis]:

That one is characterized by fairly sluggish roll response. It is difficult to be precise in terms of heading and lateral position lineup. Especially noticeable down low in lining up on the runway. I came across the threshold in the adequate region, kind of lined up and offset to the right probably more than half way. Also difficult to achieve a nice crisp bank angle response. Deficiencies warrant improvement. Between moderately annoying and moderately objectionable. Most of the time the performance was in the desired range, there was some adequate.

Runs 705-706; Conf. 1I; HQR 6 [Note: Pilot was excessively aggressive; not used in analysis]:

That one is characterized by a lot of residual oscillations, PIO's. Any attempt to tighten up on that one caused some significant oscillations in performance. Deficiencies definitely warrant improvement, in the category of very objectionable, tolerable in the sense that as a backup system you could fly it and blunder through the tasks, but only with the greatest of effort and marginal performance.

Runs 707-708; Conf. 2A; HQR 2:

That one was an excellent pitch dynamics case. Satisfactory without improvement. Really easy to get the pipper on the target in all cases. Good with negligible deficiencies.

Runs 709-710; Conf. 4A; HQR 3:

That one is definitely satisfactory without improvement. It has a good pitch control and good flight path control, and that is true of this one and also the previous one. Attitude changes rapidly followed by quick flight path change. The only deficiency I could find in the pitch axis was a slight tendency to bobble a little to aggressively after a target attitude. That seemed to be due to a small amount of pitch rate overshoot or drop back.

TABLE B-6. (CONTINUED)

Runs 711-713; Conf. 7A; HQR 3:
That one is characterized by a interesting pitch attitude response. A little sluggish but also extremely predictable and smooth. Satisfactory without improvement, with a mildly unpleasant deficiency, that is it is a little bit on the sluggish side, so it is not ideal. A little too sluggish, but I could do the task with desirable performance, very repeatable, altitude within 10 feet, and keep the pipper within a desired performance without a lot of effort. A very smooth pitch response, very predictable.

Runs 714-715; Conf. 13A; HQR 2-1/^:
That one is characterized by pitch rate overshoot, or attitude dropback. When you went to a target attitude, the nose would drop back from that. The effect of that on the tracking was essentially zero and totally compensated for because the response was crisp and very predictable. That dropback just didn't shown up in the closed loop tracking. And I was able to achieve desired performance and be very aggressive with it. I was able to hold altitude within 5 feet, felt very much in control. Even inspite of the dropback it seemed to have no effect on the ability to do the task. The crispness was the most redeeming factor.

Runs 716-718; Conf. 1H; HQR 4:
We've created a new task where its pretty aggressive and we are combining slalom and dolphin, and there may be some learning effects in this. You need a pretty crisp pitch and roll response. I find that this was a little too sluggish for Level 1. Deficiencies warrant improvement, you can do it but the workload high. It is minor but annoying deficiency. Also desired performance requires moderate compensation. I could get desired performance with the compensation. Some of the more difficult things are leveling off, climbing turns, combined level off 6 degree turn. Also the task gets lined up with the runway, it is pretty high workload.

Runs 719-720; Conf. 1C; HQR 7:
That has a particularly poor roll response, very sluggish, for this task I found that I couldn't even get adequate roll response. Especially I had problems coming across the bridge, in a climbing turn, a continuous oscillation and I never could get the pipper settled down. I couldn't do the mission. Deficiencies require improvement, adequate performance not attainable. I don't think that I was ever really out of control ' ould always back off and get the thing under control. The primary problem was lateral.

Runs 721-723; Conf. 4C; HQR 6:
That was characterized by pretty sluggish roll response. Pitch response was good. The primary pitch response would be a very sluggish roll. That showed up as a tendency for a lot of oscillations that we are trying to roll in on the target. Also a tendency to over bank when trying to combine a level off movement and

bank. There is a tendency to overbank. We did get thoroughly adequate performance, meaning we could get the pipper within 1 diameter of the target. Deficiencies warrant improvement, very objectionable, but probably you could struggle through the mission if you had that failure, and it would be sort of effective.

Runs 724-725; Conf. 1H; HQR 3:
That had a nice crisp roll response, and a good pitch response as well. You could do the task with desired performance, satisfactory without improvement even though on both runs I overshot that aqueduct turn a little bit, but I was still able to do the course pretty well. Considering the workload, still some compensation required for desired performance.

Runs 726-727; Conf. 5H; HQR 4-1/2:
That was characterized by a good roll response and a very crisp pitch response. On top of that pitch response there was a high frequency oscillation, which in some cases became very objectionable. In particular in some case, like rolling into a steep turn, it was really possible to get that pitch going, and bank 60 degrees and have a rapid pitch oscillation simultaneously. That occurred two or three times during the runs. That is a moderately objectionable deficiency, with aggressive maneuvering. The tracking was good and was in the desired region. HQR=4.5.

Runs 728-729; Conf. 5C; HQR 6:
Combination of very sluggish roll response combined with a high frequency oscillation in pitch, without the oscillation it is quite a crisp pitch response. Deficiencies warrant improvement, well beyond the Level 2 range. My major decision to make here is weather it is HQR=6 or HQR=7. Some times there was adequate performance, as long as I stayed ahead of it. As a backup system it is just as bad as it can get.

Runs 730-731; Conf. 2F; HQR 4:
The primary characteristics of that configurations were pretty good pitch response, but a marginally sluggish roll response. The pitch response would have been Level 1, but with that roll response with those two combined it moves into the deficiencies warrant improvement on Level 2. Roll is not that bad, but it is an annoying deficiency, my performance for the most part was in the desired range. Compensation was moderate.

Runs 732-733; Conf. 2G; HQR 3:
Pretty good combination of pitch and roll. Satisfactory without improvement, even on the last run where I missed a checkpoint, I was able to recover the performance as desired in all cases. The only deficiency that I could detect was that it was a little sluggish in roll, a little crisper roll response would make it a 2.

TABLE B-6. (CONTINUED)

Runs 734-735; Conf. 2A; HQR 2:
That one was characterized by nice, crisp pitch response and a nice, crisp roll response. Especially liked the roll. But actually, both were well into Level 1 with negligible deficiencies. Pilot compensation wasn't a factor. It made the task easy to do desired performance. What I liked most about that was the crispness in every axis and the lack of any residual motions. No tendency to PIO or any other ill effects.

Runs 736-737; Conf. 2I; HQR 4:
That's one of those confusing ones. It's on the borderline. Very good pitch, nice, crisp pitch response. Always desired performance in getting the pipper on the target on those ground attacks. But the roll was sluggish and I'm torn between being OK without improvement, an HQR 3 and down here, warranting improvement, HQR 4, because it's real close. I think I'm going to go with HQR equals 4 on that just because I did have problems lining up with the runway and just wasn't as crisp as it could be in roll. And, you may have noticed that, during that lineup with the runway, there were some lateral oscillations. And, that was, fighting that sluggish, slightly sluggish roll response.

Run 738; Conf. 9H; HQR 2:
We only ran one on that because the computer crashed here in the mid-point through the second run. But still, it's an excellent configuration so it's easy to rate. It's satisfactory without improvement, nice crisp roll response and a nice crisp pitch response. The only thing I noticed during the initial run there, was that there is quite a bit of pitch rate overshoot and attitude dropback. But that's not a factor when doing precision pitch tracking at all. So, say it's good but negligible deficiencies, pilot compensation really isn't a factor. Performance definitely desirable. Could be extra-aggressive with that one.

Runs 739-740; Conf. 7H; HQR 4:
That configuration was characterized by nice, crisp roll response and a marginally sluggish pitch response. Pitch response was very smooth, but for precision tracking, it's just a little bit too sluggish, especially when combined with the lateral axis. So, I think we're going to slip on that to deficiencies warrant improvement. The performance in most cases was desired, but the sluggish pitch was at least a minor and, definitely an annoying deficiency that resulted in continuous attitude bobbling throughout the task.

Runs 741; Conf. 2A; HQR 1-1/2:
That run is so good that we decided that we didn't need to make two runs. It's clearly an excellent roll case and the pitch is also very good. And the maneuver is a constant altitude slalom so clearly

satisfactory without improvement. Level 1 and did the task by comparison, having just finished doing the multi-axis task, this slalom task is much easier. Just excellent roll and compensation is not a factor.

Runs 742-743; Conf. 2G; HQR 3:
The primary deficiency in that one was a somewhat sluggish roll response, although it didn't seem to interfere with my ability to do the task significantly. The workload was certainly up a little bit, but actually it seems like it probably would be satisfactory without improvement just for that task. It's certainly not ideal. Not very crisp but definitely good enough to do the job with.

Runs 744-745; Conf. 2I; HQR 3:
That basically was characterized very similar to the previous runs. Characterized by somewhat sluggish roll response, but still well in the acceptable range, though not well into it, just barely into the acceptable range is a better way to say it. By acceptable, I mean Level 1. And it had a mildly unpleasant deficiency which was a somewhat sluggish roll response.

Runs 746-747; Conf. 13H; HQR 2-1/2:
That configuration was characterized by a nice, crisp roll response, or reasonably crisp, anyhow. Pitch response was nice and crisp but had considerable pitch rate overshoot with attitude drop-back. However, that seemed again not to be a problem. It's nice and crisp but I can put the pipper where I want it. There might be just a slight bit of bobbling here and there but it's very minor and is totally compensated for by the quickness of the response.

Runs 748-749; Conf. 13C; HQR 5-1/2:
That was characterized by good pitch response, crisp and all, but the lateral axis was quite sluggish and very difficult to be precise with. On that basis, deficiencies definitely warrant improvement and it's really a toss between being moderately and very objectionable. The biggest problem I had was getting the tipper laterally aligned on the thing. And, especially doing the side-steps on the runway, I got into significant oscillations trying to make aggressive lateral maneuvers.

Runs 750-751; Conf. 7B; HQR 6:
That was characterized by very sluggish pitch and very sluggish roll as well. Both about equally sluggish. It's impossible to really tighten up on those two axes. So deficiencies warrant improvement. There was really no tendency for the extended PIO, although there were some lateral oscillations. And, I could achieve adequate performance, so I'd say the deficiencies are very objectionable but tolerable. It's at the bottom of Level 2. And, on that basis.

TABLE B-6. (CONTINUED)

Runs 752-753; Conf. 4I; HQR 3:
That one was satisfactory with improvement, not ideal, a little bit sluggish in roll and just had to kind of horse it around. But it was pretty well behaved. And, so I'm going to put that as a marginal Level 1 case. Just barely good enough. Marginally sluggish, primarily in roll.

Runs 754-755; Conf. 6C; HQR 7-1/2:
That configuration has double deficiencies. It has a really nasty high-frequency, lightly damped mode in pitch, and a very sluggish roll. So, it's a combination of the two that makes it a very poor flying airplane. Deficiencies definitely require improvement and there are even times during the run in attempting to do tasks, that control is a definite issue. There's a lot of, especially laterally, there's a tendency, you feel like you're going to lose it laterally. However, were able to struggle through the course with it and actually get the pipper near the target in some cases. So, it's not quite considerable pilot compensation required for control because we were still doing the task. a half.

Date: 20 March 1989; Pilot B

Run 756-757; Conf. 2; HQR 2-1/2:
I was able to obtain satisfactory performance at all times. I did have some mildly unpleasant, or a negligible deficiency which did require a bit of pilot compensation.

Runs 758-759; Conf. 4; HQR 4:
I did have some deviations from the satisfactory performance standard, adequate performance was always obtained. Did have some deficiencies, they were minor. And they did require some pilot compensation.

Runs 760-761; Conf. 1; HQR 1-1/2:
Satisfactory performance was attainable at all times. Had very desirable characteristics. The one deficiency is that it is slightly slow and stick is just a touch heavy.

Runs 762-763; Conf. 5; HQR 5-1/2:
Was able to maintain adequate, but not satisfactory performance at all times. The pitch mode has the deficiency, the short term mode is very easily excited, and caused me to back off the task and be unable to obtain a satisfactory performance. Requires quite a bit of pilot compensation to avoid exciting the short term mode.

Runs 764-765; Conf. 13; HQR 2-1/2:
Was able to maintain satisfactory performance. Has a mildly

TABLE B-6. (CONTINUED)

unpleasant characteristic there in the damping ratio. But pilot compensation was not really a factor.

Runs 766-768; Conf. 6; HQR 6:
Was not able to obtain satisfactory performance. Adequate performance, however, was attainable. Very objectionable oscillation that is excited in the short term mode.

Runs 769-770; Conf. H; HQR 2-1/2:
Was able to obtain satisfactory performance the majority of the time. Couple of minor excursions, but nothing extremely unpleasant about it. But, overall good characteristics and didn't really require much in the way of pilot compensation.

Runs 771-772; Conf. I; HQR 2:
Was able to obtain desired performance the majority of the time. System is slightly under damped in roll. Didn't really require much in the way of pilot compensation. Would rate that as a minor deficiency.

Runs 773-774; Conf. C; HQR 5:
Was able to obtain satisfactory performance. It is a moderately objectionable lack of damping in the roll case and required considerable effort to compensate.

Runs 775-777; Conf. B; HQR 4:
Was able to obtain adequate performance but had numerous deviations outside the satisfactory range. Had some minor annoying tendencies that did require a little bit of pilot compensation to overcome.

Runs 778-781; Conf. C [Low-Bandwidth Forcing Function]; HQR 4-1/2:
Despite the fact that on the majority of the runs I was able to maintain satisfactory performance, the system has a very nasty lack of damping in the roll case and requires an extreme amount of pilot compensation. And, if you're not careful, it can easily be aggravated into a PIO about the roll axis. If it's flown very smoothly, very deliberately and anticipating the corrections, it's possible to maintain satisfactory performance. However, it's very difficult to do so without a lot of learning and you do have the potential of aggravating that roll case.

Runs 782-784; Conf. 2H; HQR 5:
Was able to obtain adequate but not satisfactory performance. Has an objectionable deficiency in the roll axis. Was able to obtain adequate performance with a considerable amount of effort and occasionally it caused me to back off on the pitch task somewhat, which allowed excursions outside the satisfactory range there also, trying to keep the roll under control. And it's very excitable in the roll.

TABLE B-6. (CONTINUED)

Runs 785-786; Conf. 5H; HQR 5-1/2:
Was able to obtain adequate but not satisfactory performance. It's very objectionable in the pitch case. The short term motion is very easily excited and it's difficult not to excite that. And, however, it only required a considerable, rather than extensive amount of pilot compensation to retain the aircraft in control within the adequate boundaries.

Runs 787-788; Conf. 4I; HQR 4-1/2:
Was not able to obtain satisfactory performance, adequate performance was easily attainable. Did require a moderate amount of pilot compensation to obtain it, but the deficiencies themselves were moderately objectionable.

Runs 789-791; Conf. 5C [Low-Bandwidth Roll Forcing Function]; HQR 7:
Adequate performance was only attainable on one of the three runs. System has major deficiencies. It's very lightly damped in the roll axis and has a sluggish response. Somewhat improved on the latter runs after increasing sensitivity, but still very difficult. It was in the roll axis that we were not able to obtain adequate performance. In the pitch axis, it's got a very objectionable short term excitation mode that makes it very difficult to keep up with any other of the required tasks. Controllability really never was in question.

20 March 1989; Pilot W:

Runs [illegible] [illegible]onf. 2H; HQR 2:
Controllable: Yes. Adequate: Yes. Satisfactory: Yes. We got some mildly unpleasantness. It's got a little bit of an overshoot there. It gives you a little bit of a heave each time when you let go, and when you back off it kind of heaves up a little bit then drops back down. But you can put it right where you want it to. It stays within desired criteria.

Runs 794-796; Conf. 4H; HQR 3:
Controllable: Yes. Adequate: Yes. I can get adequate performance that is satisfactory without improvement. Here's the rub. I'll say yes. It's got some mildly unpleasant deficiencies. It's got a little bit of a heave and an oscillation around your aim point but yet you can stay within about a plus or minus a quarter or a half of a degree, so it's not too bad. Some mildly unpleasant deficiencies and minimum pilot compensation required for desired performance. It's o.k. but it could be better.

Runs 797-798; Conf. 13H; HQR 4:
Controllable: Yes. Adequate: Yes. Satisfactory Without Improvement: No. It's got some deficiencies that warrant

improvement. Getting a little bit of a PIO type bobble about a plus or minus a half to three quarters of a degree around your desired. And apparently a little bit of a lag in the system essentially, and the desired performance required moderate compensation, yes.

Runs 799-800; Conf. 5H; HQR 7:
Controllable: Yes. Adequate: No. Every time you set something it bounces outside the adequate criteria there, so I'm going to say No, it's not an adequate performance. And so we're going to look at some major deficiencies and every time I moved the airplane I couldn't keep it within the adequate performance criteria.

Runs 801-802; Conf. 2H; HQR 2:
Controllable: Yes. Adequate: Yes. Satisfactory: Yes. It's a good flying airplane. It's got some minor deficiencies. But on principal I can't rate anything a one here. It's not a perfect airplane. It's got a couple of minor nits about it, just I guess probably as much as anything its that the stick is just a little bit slow to roll for me here. But the pilot compensation wasn't a factor. I could get it and hold it on a bank angle real well.

Runs 803-804; Conf. 2I; HQR 4:
Controllable: Yes. Adequate: Yes. Satisfactory Without Improvement: No. It's sluggish in the roll and especially on the tracking task I finding myself in about a plus or minus five degree PIO. I'd say PIO's causing to barely get adequate performance here. So I'm going to say moderately objectionable with adequate performance requiring considerable compensation.

Runs 805-806; Conf. 2B; HQR 8:
Controllable: Yes. Adequate: No. I can't get my bank angle, I can't maintain it even straight and level, it just drifts off and I have to work hard to keep even wings leveled and I tend to overshoot all my bank angles when I roll into a turn. Get a little bit of a PIO each time I try to track down a center line and/or the side of the runway. And I'm going to say considerable pilot compensation required for control.

Run 807; Conf. 2C; HQR 10:
Controllable: No. It's real sluggish; the sidestep maneuver there, I couldn't control it in that. Real slow to roll and sluggish, and found myself with the stick in the opposite corner. Like if I was still rolling to the right, I had the stick all the way to the left trying to stop the roll and I couldn't stop it.

TABLE B-6. (CONTINUED)

Date: 21 March 1989; Pilot W

Runs 808-809; Conf. 1; HQR 2:
Controllable: Yes. Adequate: Yes. Satisfactory: Yes. If the thing would ever stand still, I could have put it right on it, so it's that pilot compensation wasn't a factor.

Runs 810-811; Conf. 2; HQR 3:
Controllable: Yes. Adequate: Yes. Satisfactory: Yes. I'm going to say, but it does have some mildly unpleasant deficiencies here, and will give you a little bit of overshoot each time. It's got good, crisp response and it's predictable but it gives you just a little bit of an overshoot and especially on some of the larger movements gives you just an overshoot every time you go just seems like one overshoot every time.

Runs 812-813; Conf. 9; HQR 4:
Controllable: Yes. Adequate: Yes. Satisfactory Without Improvement: No. I can still make desired performance but control input is very, it's an abrupt control, the initial movement is pretty abrupt and it gives you an overshoot every time. You can just feel it in the seat of your pants there, and it kind of makes it uncomfortable to fly but I can still make desired performance, so we'll say that it requires moderate compensation.

Runs 814-816; Conf. 5; HQR 5:
Controllable: Yes. Adequate: Yes. Satisfactory: No. I don't know how to describe it. It gives you an uncomfortable feeling. It's abrupt in control, it overshoots every time and you get about two or three overshoots each time, and trying to read these and deciding what it could be very objectionable but tolerable, no that's not really it. It's more moderately objectionable but your workload, you've got considerable pilot compensation. You can still meet adequate criteria fairly easily.

Runs 817-818; Conf. 4; HQR 5:
Controllable: Yes. Adequate: Yes. Satisfactory: No. I just can't predict where it's going to be, essentially. I can get desired performance, well, it is the excursions out to adequate that make it, I can meet adequate performance with considerable compensation. I can almost make desired but it's with more compensation. Watching my stick activity I get a lot of jabs on it, because I cannot really predict where the system is going here. Considerable pilot compensation on that, just because of the frequency of the inputs I have to put in, and then the unpredictability of the system.

Runs 819-820; Conf. A; HQR 3:
Controllable: Yes. Adequate: Yes. Satisfactory: Yes. It's got

some mildly unpleasant, it's a little bit unpredictable, I don't quite get it; the initial movement I kind of end up having to stop it just before I get it, so I'm not quite predicting where it's going to go. But it's really just a little bit unpleasant there. Feels like there's a little bit of dead space in the stick, it's got a little breakout force there, is a little bit heavy maybe, I don't know how to explain it. It feels like there's just a dead zone before it's starts moving, but it's not too bad, we'll give it a minimal pilot compensation.

Runs 821-822; Conf. H; HQR 2:
Controllable: Yes. Adequate: Yes. Satisfactory: Yes. I liked the handling qualities of that one. I felt it was good and the pilot compensation was not really a factor, you could get it right where you want it to go. And forces were real nice on that one.

Runs 823-824; Conf. I; HQR 5:
Controllable: Yes. Adequate: Yes. Satisfactory: No. I find myself on that one, kind of backing out of the loop a little bit. I'm getting an overshoot and I'm having a harder time staying in phase with the forcing function there. It's right on the border line between desired and adequate performance. Just because I was out of phase a little bit more, then getting a couple of wing rocks, you know, kind of like a PIO almost on some of the bigger inputs there, I'm going to say moderately objectionable and getting adequate with considerable pilot compensation.

Runs 825-827; Conf. B; HQR 6:
Controllable: Yes. Adequate: Yes. Yes, it meets adequate criteria there but has some pretty objectionable deficiencies there. It requires extensive pilot compensation. I find myself working real hard to try to keep it, and even the tune up on the sensitivities there, still the aircraft controls feel sluggish on that, although the response is sluggish. I find that it's a little bit unpredictable where its going to roll.

Runs 828-830; Conf. 1A; HQR 2:
Controllable: Yes. Adequate: Yes. Satisfactory Without Improvement: Yes. The airplane handles pretty well. It's got a good crisp roll response but this task is pretty hard to evaluate, how well you're doing. The airplane feels like it flies pretty well; and because the task is so difficult. I'm having a hard time between a two and a three here. Pilot compensation not a factor. It felt like it was a pretty good airplane.

Runs 831-832; Conf. 2H; HQR 3:
Controllable: Yes. Adequate: Yes. Satisfactory: Yes. It's got some mildly unpleasant deficiencies there. It's a little bit abrupt causing me to overshoot each time I move it but the response is good

TABLE B-6. (CONTINUED)

overall so it's minimal compensation just to correct for that overshoot on it.

Runs 833-835; Conf. 4H; HQR 5:
Controllable: Yes. Adequate: Yes. Satisfactory Without Improvement: No. I'm having a hard time; I can get it within the desired criteria, but I can't really narrow it down. It's I think a little bit of a predictability of where I'm able to move it, I'm having a hard time predicting where it's going. It's within the desired criteria, but I don't think I'm really meeting a desired performance. I mean it's within the plus or minus 2 and one half but it's consistently off the center. It requires considerable pilot compensation. Even though I'm making desired performance, I'm a little bit higher workload than desired performance allows. If I can't get the pitch close I'm not following the roll very well at all. I'm more concerned initially; once I get the pitch close then I find myself working on the roll; but until I get the pitch close I'm concentrating on it more.

Runs 836-837; Conf. 2B; HQR 6:
Controllable: Yes. Adequate: Yes. Satisfactory: No. I can meet the pitch, it's not a problem here, I can get it pretty good in pitch but in roll essentially is out of phase. I'm out of phase with the roll especially when I've got larger inputs almost completely out of phase with them, and I'm adding a lot of lead to the system too, to try to stop it when I'm rolling. So I'm going to find it very objectionable but tolerable deficiencies. I can get adequate performance with extensive compensation.

Runs 838-839; Conf. 5H; HQR 6:
Controllable: Yes. Adequate: Yes. Satisfactory: No. Got what I consider to be very objectionable deficiencies here. I'm getting a big overshoot every time I move. The pitch seems a bit abrupt and then overshoots every time, you know, I'm getting probably about two degrees a lot of time on a bigger move. I overshoot about two degrees each time. So adequate performance requires extensive compensation. Roll seemed fairly good there but once again, when I'm chasing pitch, I don't get a real good look at the roll.

Date: 21 March 1989; Pilot B

Runs 840-842; Conf. 2H; HQR 4-1/2:
It was very difficult to maintain performance within the satisfactory limits, occasional diversions in the pitch axis, more diversions than the roll axis. The deficiencies were rather annoying and relatively minor. It required a fair amount of pilot effort.

TABLE B-6. (CONTINUED)

Runs 843-845; Conf. 4I; HQR 5:
Was not possible to maintain satisfactory performance adequately. Performance was obtainable, however, some moderately objectionable characteristics in that the roll axis was very easy to incite into a PIO. The damping ratio seems to be somewhat lower than it should be. And in an attempt to stop the roll exactly where you want to, it has a tendency to get slightly behind the aircraft response and induce PIO in roll. The pitch axis is also less then fully desired. Although I do not have as clear a picture in my mind as to exactly what was wrong with the pitch axis, but coupled with the roll, I was having to back off and concentrate more on the roll task. And that did not permit me to devote full attention to pitch axis. The response characteristics there also seemed to be slightly less damped than they should have been.

Runs 846-847; Conf. T6; HQR 2:
With no other tasks to distract you from the throttle task, it was quite simple and it did require some pilot attention and compensation because it was obviously would not stay where it was supposed to stay, therefore can't rate it as a ONE, but was otherwise quite simple to take care of.

Runs 848-850; Conf. 2T6; HQR 2-1/2:
Although I was not able to maintain desired performance through the entire runs on all three occasions, primarily due to unfamiliarity with the task, with a little more practice I feel that desired performance should be able to be obtained without too much difficulty. The only exclusions were when task interaction and unfamiliarity interacted to cause the operator to get slightly behind the system and back off on the task, enough to allow one parameter, or the other to exceed the desired limits. At no time were the satisfactory limits exceeded. No significant deficiencies on either the throttle case or the pitch case, flew fairly well, but the interaction between the two does require a bit of pilot concentration.

Runs 851-853; Conf. 4T6; HQR 4:
It was difficult to maintain desired performance, or a satisfactory performance at all times. Adequate performance was always obtainable except in the one instance where I responded in the wrong direction to, a problem cue, problem in the wrong direction, pilot error as opposed to anything else and that particular deviation should be ignored, partly due to unfamiliarity with the cues provided. The pitch axis did have a minor problem with it, coupled with the additional workload of the throttle task which is somewhat distracting in that the throttle cues do not match the pitch cues. It is quite unnatural to have to add power when you have the nose buried, and pull power off as you are tracking something above the horizon and you are accelerating. It is somewhat distracting and makes you stop and think a little bit. At no time was there serious

difficulties encountered but was a much higher workload than otherwise would have been.

Runs 854-856; Conf. HT6; HQR 2-1/2:
Adequate: At all times. Satisfactory: About 90% of the time. Momentary deviations easily recovered due to forcing function diversions. The work level with the throttle task is somewhat higher than a straight pitch task, or a roll task, rather. And found no deficiencies in the roll response nor on the throttle response. However, due to the lack of additional cues the work level is somewhat increased. The distraction of the forcing function on the throttle quadrant is much less so than with the pitch case, as the relationship between roll attitude and throttle position is not nearly as well ingrained in the pilot as that of pitch attitude and throttle position. Therefore, it was much less of a distractor in the roll case than it was in the pitch case.

Runs 857-859; Conf. 2HT6; HQR 3-1/2:
Overall, no major deficiencies in any of the systems as far as axes. It was difficult to maintain all parameters simultaneously in the desired range. The adequate range was easily obtainable. It required quite a bit of concentration to maintain the parameters as desired though. No major deficiencies noted in either the pitch or the roll axis.

Runs 860-862; Conf. 4HT6; HQR 5:
Was able to obtain adequate but not satisfactory performance. Did entail a considerable pilot workload. Satisfactory was not attainable. Adequate was attainable. It does have some moderately deficiencies in the damping on the pitch axis. It has a tendency to bounce in short mode that is excited. It did take a bit of work to get around that. It was rather difficult to keep everything in context with the throttle movement also. It was somewhat distracting in that the throttle cues were in direct opposition to the pitch ques provided from the horizon. And that provided an additional distraction that had to be compensated for.

Runs 863-864; Conf. 2H; HQR 1:
As far a regarding to task it was very docile and the pitch handled those with little roll. The airplane flew well, I was able to obtain desired performance with no problems, satisfactory performance. Low workload, the only problems were with reading the altimeter and that would account for any deviations that I had, and in a couple instances I did misread the altimeter.

Runs 865-866; Conf. 5H; HQR 2-1/2:
I was able to obtain satisfactory performance without any trouble. It did have a mildly unpleasant difficulty with the short term mode on the pitch axis in the damping, but with minimal compensation to avoid that I was able to handle it with no problem.

Runs 867-868; Conf. 2H; HQR 1:
The aircraft had very good handling qualities, no deficiencies whatsoever. Very easy to maintain altitude and bank angle, was able to maintain satisfactory performance the entire time with no particular pilot compensation required.

Runs 869-871; Conf. 2B; HQR 6:
I was able to maintain satisfactory performance through out the flight envelope except for the sidestep maneuvers. On the sidestep maneuvers, I was barely able to maintain adequate performance. In the sidestep maneuver with the high rate roll required, it has a very objectionable tendency in that it is somewhat sluggish, and not very well damped. It required extensive pilot compensation to remain within the adequate range.

<u>Date: 22 March 1989; Pilot W</u>

Runs 872-873; Conf. 2H; HQR 3:
Controllable: Yes. Adequate: Yes. Satisfactory: Yes. There was a little bit of an overshoot on each move, and you get a couple of wanderers in and around the target area, maybe a quarter of a degree or so a couple of times. It has some mildly unpleasant deficiencies with that overshoot.

Runs 874-875; Conf. 4H; HQR 6:
Controllable: Yes. Adequate: Loosely defined, we could make adequate performance. Satisfactory: No. It has five or six kinds of overshoot. Each time I try to make a correction there it gets hard to predict where there airplane is going to go. From overshooting I'm getting a big pause it seems, a lot of delay, lag, in the system. I'm having to add some lead to it. I will say it is very objectional le with tolerable deficiencies. I can get it to meet the performance criteria by essentially taking myself out of the loop a little bit there.

Runs 876-878; Conf. 5H; HQR 6:
Controllable: Yes. Adequate: Barely make adequate performance here. Satisfactory: No. Essentially I'm getting overshoots every time. The stick force is good, the predictability not too bad, but I'm getting overshoots every time I go around the aim point, plus or minus a ball width. I can get it back and settle it down with extensive pilot compensation.

Runs 879-880; Conf. 2H; HQR 3:
Controllable: Yes. Adequate: Yes. Satisfactory: Yes, I can make desired performance. It has some mildly unpleasant deficiencies. The control harmony is poor, it is a lot wider in pitch than in roll and fairly heavy stick forces. I can put it where I need to.

TABLE B-6. (CONTINUED)

Essentially heavy pitch forces. I have to use a little bit of pilot compensation because it is heavy in my hand.

Runs 881-882; Conf. 4H; HQR 4:
Controllable: Yes. Adequate: Yes. Satisfactory: No. I can make desired performance but the stick forces and control harmony are off. It is sluggish to my pitch and then putting in huge pitch inputs to get it to move, but every time I do that I get a little bit of a roll oscillation. It is essentially minor but annoying deficiencies. I can still get desired performance.

Runs 883-884; Conf. 2H; HQR 4:
Controllable: Yes. Adequate: Yes. Satisfactory: No. I can maintain desired performance but it is abrupt when I try to reverse directions with the stick or when I essentially stop my roll it gives me an abrupt feeling trying to heave me around the cockpit, maybe a slight overshoot on it. Minor but annoying deficiencies, I can meet desired performance.

Runs 885-886; Conf. 2F; HQR 7:
Controllable: Yes. Adequate: No. Initially the response feels sluggish but it isn't a roll rate problem, its just how slow it is to respond. The initial response is sluggish, I can't quite get adequate performance, I can't maintain a bank angle within probably plus or minus 5 degrees around the desired bank angle. I'm about a diameter or a half (plus or minus) when I trying to maintain the flight path marker there. I can still control the aircraft, though I can't get adequate performance with maximum tolerable pilot compensation.

Runs 887-888; Conf. 2B; HQR 8:
Controllable: Yes. Adequate: No. We have a real problem. Essentially control harmony is very abrupt in pitch, which makes it very uncomfortable to fly the airplane. It has some major deficiencies with considerable pilot compensation required, essentially I have to give up on any kind of roll pass because the pitch is so sensitive and so abrupt, but the roll is not the problem. Any kind of correction after roll gives a very abrupt pitch up or down.

Runs 889-890; Conf. 2H; HQR 4:
Controllable: Yes. Adequate: Yes. Satisfactory: No. I have a little PIO around each bank attitude, so my workload is up a little bit. I can still maintain desired performance, plus or minus 2 degrees on the PIO, I can get it to settle down. I can get desired performance with moderate compensation.

Runs 891-892; Conf. 2B; HQR 7:
Controllable: Yes. Adequate: No. I get into a plus or minus 10 degree lateral PIO, a real low frequency one. The controls in the

lateral are real sluggish and slow to respond. I have real heavy stick forces associated with that, I also get a very abrupt feeling of PIO in the pitch axis. I get bounced out of my seat quite a bit when I'm trying to control the attitude pitch wise. We have some major deficiencies there, controllability is not in question but we couldn't get adequate performance.

Runs 893-894; Conf. 2H; HQR 4:
Controllable: Yes. Adequate: Yes. Satisfactory: No. I can make desired criteria, however, every time I'm in a bank and trying to set the pitch, I get an overshoot; I can feel myself bouncing out of the seat every time. So it's a minor but annoying deficiency, but I can still get desired performance.

Runs 895-897; Conf. 2I; HQR 4:
Controllable: Yes. Adequate: Yes. Satisfactory: No. I can maintain, or keep desired performance but I'm getting an uncomfortable heave every time I roll fast. In any kind of quick rolling maneuver, when I start to roll out, the airplane heaves up and gives me a pitch overshoot probably about a half a meg of g's or so, almost feels like, and it just tosses me out of the seat. That's annoying but I can still maintain desired performance with it.

Runs 898-899; Conf. 5H; HQR 6:
Controllable: Yes. Adequate: Yes. Satisfactory: No. Very noticeable overshoots. Every time you pitch, especially, the roll doesn't seem to be too bad, but you get three or four overshoots and the first couple of them are very significant but you can still maintain adequate performance in that criteria. It's not so much that it requires a lot of workload, but you really have to just take yourself out of the loop to let it settle down. The airplane will settle down if you can just freeze the stick here.

Runs 900-901; Conf. 1H; HQR 5:
Controllable: Yes. Adequate: Yes. Satisfactory: No. It's very difficult to predict where I'm going to get the pitch; the control seems a little bit sluggish and then I always tended to be about three or four degrees past where I thought I was going to be. Like, if I was shooting for five I'd end up at around eight degrees pitch attitude initially. I could get it back down but it took considerable pilot compensation.

Runs 902-903; Conf. 2H; HQR 3:
Controllable: Yes. Adequate: Yes. Satisfactory: Yes. Just get a slight overshoot each time I make a gross correction error, and then bobbles about twice but it's not a real bad problem. So, it's got some mildly unpleasant deficiencies. Not much pilot compensation required.

TABLE B-6. (CONTINUED)

Runs 904-905; Conf. 1H; HQR 4:
Controllable: Yes. Adequate: Yes. Satisfactory: No. It's got some deficiencies, in fact it's a little bit sluggish to my input and hard to predict where the pitch will end up, and I miss them generally by about a degree, causing just a little bit harder task for me and requiring about a moderate pilot compensation. I can still make desired criteria.

Runs 906-907; Conf. 4H; HQR 6:
Controllable: Yes. Adequate: Yes. Satisfactory: No. It takes probably three or four inputs to get it to even settle down while I'm trying to correct minor deviations, and plus when I make larger corrections, it overshoots by a considerable amount. Probably two or three times I get into a little bit of a PIO as I try to correct that, and just those minor deviations, can't quite get them. It's hard to predict where it's going to be so I'm bouncing around plus or minus a quarter of a degree on either side of my aim point there trying to get it to settle down on the five degree hash mark and especially in climbs, so I'll say adequate performance requires extensive pilot compensation.

Runs 908-909; Conf. 6H; HQR 8:
Controllable: Yes. Adequate: No. Pretty serious PIO tendency there on the airplane; I can even get it into almost a divergent PIO. The only way I could get it to settle down was essentially get out of the loop. And so I'm going to say with considerable pilot compensation required for control, I had to constantly get out of the loop and really fight to keep it in control while I was trying to do a change of a pitch attitude there, like level off especially; a couple of times I could hardly do it.

Runs 910-911; Conf. 2H; HQR 2:
Controllable: Yes. Adequate: Yes. Satisfactory: Yes. It has some pretty good handling qualities. I feel pretty good about flying the airplane and pilot compensation wasn't really a factor.

Runs 912-913; Conf. 2G; HQR 1:
Controllable: Yes. Adequate: Yes. Satisfactory: Yes. It was a really nice airplane to fly, and I'm going to say it was excellent, highly desirable.

Runs 914-915; Conf. 2C; HQR 9:
Controllable: Barely. Adequate: No. Essentially I cannot maintain a steady bank angle when I roll in any kind of turn, and when I do that sidestep it's all I can do to control the airplane.

Runs 916-917; Conf. 2H; HQR 3:
Controllable: Yes. Adequate: Yes. Satisfactory: Yes [illegible] ole of little bobbles in and around each desired heading and [illegible] red pitch angle, but it wasn't really too bad. Require just [illegible] e,

maybe two corrections for each time you set a pitch attitude, or a roll angle. I'm going to say minimal pilot compensation required. Mildly unpleasant deficiencies.

Runs 918-919; Conf. 4I; HQR 7:
Controllable: Yes. Adequate: No. I couldn't maintain level, like bank angles within plus or minus five degrees; I was outside of that, and I'd get into a little P.I.O. each time I would try to make a correction in the roll. In pitch it wasn't quite as bad though, but I still couldn't maintain adequate performance here. But controllability was not questioned.

Date: 23 March 1989; Pilot W

Runs 920-921; Conf. 2H; HQR 3:
Controllable: Yes. Adequate: Yes. Satisfactory: Yes. Just a little bit of a problem with fine adjustments here, but it's really not too bad. And just because I can't get at the last quarter of a degree or so to correct, I kind of miss it. The smallest correction I can make is about a half of a degree and it takes me a couple of times to get it right on the precise attitude where I want it. So I'm going to say it requires a minimum pilot compensation.

Runs 922-924; Conf. 4H; HQR 4:
Controllable: Yes. Adequate: Yes. Satisfactory: No. I'm getting some pitch overshoots. When I aggressively track, I'm overshooting and essentially predicting where I'm stopping the pitch I'm missing by about a degree each time, causing me to overshoot here; and about two to three times each time I'm making an aggressive change here. So I would say it's minor but annoying deficiencies. I can still maintain desired performance.

Runs 925-927; Conf. 5H; HQR 4:
Controllable: Yes. Adequate: Yes. Satisfactory: No. Giving me some overshoots on all the major pitch corrections. There are about two overshoots but it's not really taking a lot of compensation to dampen those out for me. So, it's minor but annoying deficiencies. It just doesn't take a lot to get rid of the overshoots here.

Runs 928-929; Conf. 6H; HQR 6:
Controllable: Yes. Adequate: Yes. Satisfactory: No. I can get adequate performance but often times I'm stop-to-stop on the stick here. It's quite sluggish in response and like I say, a couple of times I bounced off the forward stop trying to initiate a level-off there at one thousand feet and eight hundred feet. And when I was at four hundred feet trying to level off, I essentially just backed out to get a stable platform again before I pulled back up and climbed to

eight hundred feet. But where I had time to level off I could stay active in the loop and settle it down with just short jabbing inputs there. And so I'll say that adequate performance required extensive compensation.

Runs 930-931; Conf. 2H; HQR 2:
Controllable: Yes. Adequate: Yes. Satisfactory: Yes. Able to maintain bank angle and desired headings real well, and would say good with negligible deficiencies. Flew pretty well, wasn't perfect though.

Runs 932-933; Conf. 2I; HQR 3:
Controllable: Yes. Adequate: Yes. Satisfactory: Yes. It's got a little bit of sluggishness, kind of slow to respond to the stick input, but it was causing me to overshoot, maybe once, on each bank angle input there but it's really not noticeable. It's nice and steady in your hand, and it's got some mildly unpleasant deficiencies there; it takes a little bit of compensation to overcome those.

Runs 934-935; Conf. 2B; HQR 7:
Controllable: Yes. Adequate: No. I'm overshooting bank angles by probably about thirty degrees sometimes, and missing the roll out. Can't roll out on a desired point, like point it toward the aqueduct I missed that, you know by about fifteen/twenty degrees overshoot in my heading angle there, so I can't get adequate performance for maintaining and holding a bank angle here. So we'll say, can't attain adequate performance, controllability was not in question.

Runs 936-937; Conf. 2H; HQR 2:
Controllable: Yes. Adequate: Yes. Satisfactory: Yes. The airplane flies real nice. I flew it initially on about at least the first half of that first run. Kind of like the last one, and so my bank angle predictions were a little bit off, but it wasn't this airplane's problem, it was just left over learning from the last one. So, this one has good handling qualities. I didn't find my compensation to be a big factor in the desired performance.

Runs 938-939; Conf. 2B; HQR 6:
Controllable: Yes. Adequate: Yes. Satisfactory: No. Very sluggish in roll and pitch response, causing me to mispredict rollout in bank angles. I can get adequate performance but I find myself adding a lot of lead to the system and really required extensive pilot compensation to get adequate performance.

Runs 940-941; Conf. 5H; HQR 6:
Controllable: Yes. Adequate: Yes. Satisfactory: No. Got a real problem, there's a very quick buildup of pitch rate, causing me to back off and then I'm undershooting, so I back off too quick, essentially; because I think this is how quick the pitch rate builds

up, or something. So I'm backing off and I undershoot my pitch angles by a couple of degrees each time I try to, and especially level off. And when I was at four hundred feet, I backed off enough that I went down to three hundred and fifty on that one just because of how much I had undershot the pitch angle change there. So, I'm going to say; that's very objectionable because I'm missing it every time by two or three degrees there, especially in the pitch. The roll doesn't seem to be too bad, but adequate performance required extensive pilot compensation.

Runs 942-944; Conf. 4I; HQR 7:
Controllable: Yes — Barely. Adequate Performance: No. It's got a real problem with control harmony here. It's sluggish in pitch and very crisp, and in the roll response and the two combined caused me to overcontrol in roll, and undercontrol in pitch. I can't make what I consider adequate performance here because of those, but controllability is not in question. You can still fly the airplane, it's just that you can't get good enough performance because of the poor control harmony between the two.

Runs 945-947; Conf. 4H; HQR 5:
Controllable: Yes. Adequate: Yes. Satisfactory: No. Got pretty heavy or sluggish in pitch response causing me to undershoot my altitudes on the level-outs a couple of times there, and essentially moderately objectional deficiencies. I can get the performance but it just takes quite a bit of thought and compensation here, because there's a little bit of control harmony difference between the roll and the pitch but mostly just the sluggishness in the pitch control.

Runs 948-949; Conf. 5B; HQR 9:
Is it Controllable?: Tough question. Yes, it is controllable. But it's got some major problems, there, real sluggish in both pitch and roll. And essentially it's causing me to overshoot both in roll and in pitch commands. It's hard to predict where it's going to be, and a couple of times there it required intense pilot compensation to retain the control there.

Runs 950-952; Conf. 2I; HQR 5:
Controllable: Yes. Adequate: Yes. Satisfactory: No. It is sluggish in pitch and roll, and when I really try to aim it, using the flight path marker there, I couldn't maintain desired performance. I couldn't get adequate, I couldn't get desired performance, thereby, just because of the sluggishness in the pitch and roll; and I could get only adequate performance.

Runs 953-954; Conf. 2H; HQR 2:
Controllable: Yes. Adequate: Yes. Satisfactory: Yes. Pretty good flying airplane. I didn't feel I was a big factor in getting it to do anything it was to do.

TABLE B-6. (CONTINUED)

Runs 955-956; Conf. 1H; HQR 3:
Controllable: Yes. Adequate: Yes. Satisfactory: Yes. What I'm looking at is that it's a little bit hard to predict exactly where you're going to get the pitch. I'm overshooting pitch by about two degrees but there are no oscillations or anything, so it's pretty easy to correct back to it. But I'm just missing my aim pitch angle about two degrees or so each time I try to set the pitch. But it takes just a little compensation to get it back, so we'll say that it's got some mildly unpleasant deficiencies, with minimal pilot compensation.

Runs 957-958; Conf. 6H; HQR 7:
Controllable: Yes. Adequate Performance: No. I couldn't meet the adequate criteria for aiming with the flight path marker there; I'd miss outside the requirements for that, and also when I'd set the pitch attitude I'd miss the required pitch attitude there. It was sluggish in pitch, resulting in overshoots; probably about four for each kind of gross move in the pitch command there, and so adequate performance wasn't attainable but controllability wasn't in question.

Runs 959-960; Conf. 2C; HQR 10:
Controllable: No. Just too sluggish and in roll there is too much of a delay and I'd find myself essentially backing out of the loop to regain some semblance of control in the roll axis; and it rolled so bad. There is a little bit of a PIO problem in the pitch, possibly. I could induce it a little bit, but that was mainly trying to control the roll. And essentially I backed out of the loop about twice on each run trying to get the roll oscillations to stop.

Runs 961-962; Conf. 1H; HQR 4:
Controllable: Yes. Adequate: Yes. Satisfactory: No. I'm going to say "No," but I'm going to qualify it in the fact that maybe it's just the sim that's causing it. Roll response is pretty crisp but when I try to refine roll, especially when I get up into a bank I'd get about three or four physical bounces in the simulator. So, it didn't affect really the desired performance but it was an annoying deficiency there for me. So I could get desired performance. And I don't know if it's the sim or what.

Runs 963-964; Conf. 2C; HQR 9:
Controllable: Yes. Adequate: No. We're talking very, very sluggish in roll. Got some major problems there with that. It's causing me to sometimes overshoot probably thirty to forty degrees. I was able to control it, but with only intense pilot compensation there. I think the average guy could control it, if you just put in lots of lead.

TABLE B-6. (CONTINUED)

Date: 23 March 1989; Pilot S

Runs 965-967; Conf. 2H; HQR 4:
I felt like I got desired performance on most of the runs. The ones with particular corrections I made where I did, I was primarily in overshoots not computing the lead-in points correctly, but moderate pilot compensation required because of those lead points. The biggest problem on that, and the pitch of course that we are dealing with, there seems to be quite a bit of break-out force or friction in the system. The sensitivity is right but it takes quite a bit just to make just a small motion to break it out of the friction band right around center neutral point.

Run 968-969; Conf. 4H; HQR 6:
I felt like I only got adequate performance on the runs, primarily again due to the overshoots and a little bit of lag in the system. The workload for myself for compensation went up quite a bit. I'll call it extensive.

Runs 970-971; Conf. 5H; HQR 6:
I got adequate performance throughout the maneuvers, however, it required extensive compensation. I actually found myself backing off in order to maintain adequate, or be able to get adequate and nothing less.

Date: 24 March 1989; Pilot S

Runs 972-973; Conf. 2H; HQR 2:
Desired performance achieved throughout the task. I didn't feel that pilot compensation to accomplish it really a factor.

Runs 974-975; Conf. 4H; HQR 3:
I felt like I got desired performance on all; there was one exception when I overshot one hundred feet. But for some reason I got fixated on my pitch picture and lost track of the altimeter readout. I just overshot once. Corrected it. I would say minimal compensation. Still tracks real well.

Runs 976-977; Conf. 5H; HQR 3:
I still felt like I got desired performance on both tasks, although the first one wasn't quite as good as the second. Still, compensation wasn't very heavy on the pilot's part.

Runs 978-980; Conf. 1H; HQR 4:
Still felt like I got desired performance. The reason I wanted the third ride was because on the second one I got outside adequate but my compensation wasn't very high. I mean I got some outside the adequate performance but my compensation wasn't very high. So, on

the third one I worked harder but was able to achieve the desired; because of the moderate compensation but I can still achieve desired performance level. There was a little delay in there between when you actually make an input and see any change on either the waterline or the flight path marker seems to follow by about one second and one half to two seconds. But the damping was a little bit lower than probably it could have been for optimum which caused it to bounce around a little bit and give you small overshoots. But like I said, when I drive my compensation up a little higher, I can still get desired. If I get a little lazy then I get into adequate, and of course that's not valid.

Runs 981-982; Conf. 6H; HQR 5:
This time I felt like I only got adequate performance on the runs, primarily due to control of the pitch. It required considerable compensation. What I found was I was smoothing my inputs rather than making nice, crisp inputs because of the dynamics that we had installed. I was smoothing in a little bit more larger lead points, smoother controlled inputs rather than nice, crisp inputs to achieve level-offs and pitch changes.

Runs 983-985; Conf. 7H; HQR 5-1/2:
I feel like I got only sustained adequate performance throughout the tasks. And I'm tossed between considerable and extensive compensation, so I'm going to have to go with an intermediate rating here, because of the compensation level. The pitch overshoots that I was seeing, once you get a rate going, a pitch rate tended to overshoot a little bit more than I had expected, which required more compensation on my part to keep it within the one diameter deflection.

Runs 986-987; Conf. 9H; HQR 4:
With the exception of the last run there, the one overshoot descending through six hundred feet because of my focus on pitch attitude, I think I got desired performance throughout both runs within the tolerance specified, bar compensations. What I'm finding out is that before, where I was trying to get the flight path marker to the desired target either up or down now, I'm going more because the dynamics of the stick is moving the waterline to that, and letting the flight path marker catch up. More and more I'm smoothing the inputs because the maneuverability of the airplane is such that I'm flying more of a curved flight path in the climbs and descents, rather than getting specifically on a certain glide path without making changes; kind-of rounding it and letting the flight path marker catch up.

Runs 988-989; Conf. 13H; HQR 4:
I felt I had desired performance throughout both tasks, however, compensation was probably moderate due to the light damping involved

in the lead points, etc. The stick forces and the response of the flight path marker of the airplane in response to the stick motion was a lot better than some of the previous cases, but because of the damping, tended to cause a little bit of an overshoot. But you could point the airplane much quicker, but you had to use some lead point to keep realizing that once you've reestablished the pitch, let's say to level off or to initiate some change in your flight path, that the flight path marker wasn't going to go initially to it and stabilize, it was going to overshoot slightly and then oscillate about, until it damped out. The damping wasn't real high. So, what I found myself doing was making about three inputs for one change. Let's say that if I'm in a climb and I want to level off; I push the stick forward, the flight path marker starts moving down, I've actually got the waterline below the level flight attitude, I'm going to level off, then as it gets close to it, I bring it back up to it and look and see if the flight path marker is actually going to level off at level flight and also the altitude, make sure of course that it's going to correspond within the tolerances and then make maybe one or two small corrections in there, so for every change that I want to make I'm making about four changes in the stick.

Runs 990-991; Conf. 2H; HQR 4:
Felt like I had desired performance. The one area that might have possibly caused some problems was, like I say, on the last side step to the left side of the runway it's tough for me to tell if I was within one, it looked like I was, so I'll consider it desired. However, because of that one and one other turn, the pilot compensation was probably at the moderate level. Overall I think this task is a little harder than the dolphin.

Runs 992-994; Conf. 2I; HQR 5:
Overall, I felt like I sustained adequate performance on all the maneuvers during the real high gain task, lined up on center line and also making the last runway so that solved most of the problem. Considerable pilot compensation overall; some PIO tendencies noted during the higher gain task, lateral PIO. With the high gain task where you are down close to the runway, you're diving and you've got very small distances that you are trying to correct, I found myself overcorrecting and then trying to get back, and that's where I got into the PIO.

Runs 995-996; Conf. 2H; HQR 4:
Desired performance. I felt like I got that throughout both tasks. However, it required moderate pilot compensation, not necessarily because of the performance of the flight control system, but a large extent due to the task at hand. The biggest requirement for workload or compensation, again, was the side step, or lining up on the runway, making that a first correction lining up on the runway and then making a side step to the left edge line.

TABLE B-6. (CONTINUED)

Runs 997-998; Conf. 2B; HQR 5:

Felt like I got only adequate performance sustained throughout the maneuvers, primarily because of the ability to roll to and maintain a specific bank angle, whether it be zero or sixty, because of the dynamics of the system. There were overshoots and some oscillation of P.I.O. tendencies about it with considerable pilot compensation required on my part because of that. You have to kind of smooth out the input and go more to a ramp, as opposed to a step. And likewise, once you've got the roll established, to stop the roll at a specific bank angle you've got to do the same in the opposite direction. Just stop it and stabilize it whether it be at zero or sixty or seventy. Whatever kind of bank angle you are trying to stabilize.

Runs 999-1000; Conf. 2H; HQR 2:

Desired Performance. I felt like I got that on both runs at all times. And I didn't feel it really that there was much compensation required on my part at all. Everything was real good in terms of the flight control system. The break-out force was still a little high but that's a function, I think, of the simulator more than anything else. But bank control of roll out points, lead points, etc., is very easy.

Runs 1001-1002; Conf. 2C; HQR 6:

I felt like I really only had adequate performance throughout, primarily due to the ability that I had to precisely control bank angle, and I found myself oscillating back and forth. I noticed it more on wings level since I don't have any kind of a bank reference when I'm out of winds level condition. And that drove my compensation workload up considerably, up to the point where I would say it was extensive.

Runs 1003-1004; Conf. 2I; HQR 4:

Felt like I had desired performance on both tasks and all the sub tasks within the task. However, it did require moderate pilot compensation, which was probably because of, the best I could tell, maybe a time delay that was in there. Damping seemed a little bit light but still okay, stick forces were for roll a little bit high but that's not a factor. And the stick force per deflection was better. So the best thing I can think is that it seemed to be a little bit of delay in the system in terms of when the input was made and then when the symbol reacted.

Runs 1005-1006; Conf. 2H; HQR 4:

Felt like on all the tasks that I got a desired performance, there were a couple of overshoots but it was primarily due to my concentration on some other factor and allowing that to happen. It required moderate compensation on my part to accomplish the task.

TABLE B-6. (CONTINUED)

Runs 1007-1008; Conf. 4H; HQR 5:
I felt like I had adequate performance primarily due to the performance in the pitch axis as opposed to the roll. Roll felt real good and stable. Pitch tended to overshoot a little bit. I found myself overshooting on both the top and bottom 5 degrees and then the target. Compensation did go up from last time. Up to the considerable level for compensation -- adequate performance. I felt real comfortable with the performance in the roll axis with the pitch I had a couple overshoots there in excess of the 1 diameter. Not controlling it within the 1 diameter.

Runs 1009-1010; Conf. 2B; HQR 5:
Adequate performance on the task and subtask primarily due to the roll axis. I had trouble going to and sustaining a constant bank angle precisely. It tended to wallow a little bit and wander back and forth. The compensation of workload on my part was considerable. The pitch seemed not to be a problem. It was not perfect and seemed to be much better in terms of predictability and control forces and rates. The roll seemed so stiff but once you got it moving you had a hard time stopping it. It never wanted to stabilize, there was very little damping with a very high roll mode time constant. It took a long time to stabilize the roll rate you commanded.

Runs 1011-1012; Conf. 5H; HQR 5:
Adequate performance on both runs. Considerable pilot compensation. Primarily the problem here was the pitch axis, very little damping. Overshoots tended to be the biggest problem, controlling and then having the flight path marker deviate around the desired pitch point that you're trying to pick. Roll seemed fine. I found myself concentrating on the pitch, as I was pulsing the stick I tended to make a little bit of a control harmony problem, where I was inputing some roll ratcheting with it, to control the pitch.

Runs 1013-1014; Conf. 2H; HQR 4:
Desired performance sustained throughout both tasks. Tasks required moderate compensation on my part. It is a good task itself. No axis was better or worse than another. I thought they were both mutually pretty good.

Runs 1015-1016; Conf. 4H; HQR 5:
Sustained adequate performance on all maneuvers -- desired performance was accomplished at most then, however there are some excursions, so they are all adequate. Compensation went up a little bit, but I couldn't pick out which axis was the cause of it. It seemed to have more pitch excursions than roll excursions. It bumped me up from desired to adequate.

Runs 1017-1018; Conf. 6H; HQR 5:
Adequate performance due to response in the pitch axis. Real heavy

stick forces. The airplane seemed very unmaneuverable. I took a considerable amount of stick deflection and force to get the nose to track, it was very stable but it was hard to get it going and make it point where you want it. Considerable pilot compensation. I saw no problems in the roll axis at all. Airplane was very maneuverable. I had a hard time pointing the nose where you wanted it. The airplane was very unmaneuverable, combined with the heavy slick force. It took a lot to get it up and one you released some back pressure to get the most started -- it almost didn't stop where ever you released it. A couple I stair stepped on.

Runs 1019-1020; Conf 2C; HQR 6:
I felt like I had adequate performance throughout, primarily due to lack of precise control of roll and bank angle. Extensive compensation required because of that. Once the rate had built up it was tough to get it to stop and it tended to take a long time to damp out and settle down to a specific bank angle. No problems with pitch. The large heading changes didn't necessarily aggravate roll problems, however a large sustained roll in the 60 degree bank and hold it for 5 seconds.

Runs 1021-1022; Conf. 4I; HQR 4:
Desired performance all the time, but to get it I had to back off and smooth my inputs making them more ramps than step inputs. Primarily in the pitch axis but also in the roll axis. Moderate compensation was required for the task.

Runs 1023-1024; Conf. 5B; HQR 5:
Adequate performance, some problems stabilizing roll and bank at specific limits. There was some problem with the short period tending to give me some jerkiness with the pitch axis, as far as being able to directly point the waterline where I wanted it. Considerable compensation required by me or the task.

Runs 1025-1026; Conf. 2H; HQR 3:
Minimal pilot compensation and I got desired performance on both tasks and subtasks. I didn't see any problem with either axis, both pretty good.

APPENDIX C

ANALYSIS OF PILOT PERFORMANCE DATA

The fixed- and moving-base simulations performed in the course of this study yielded a large data base on pilot performance in a closed-loop tracking task. These data, listed in Appendices A and B, are unique in providing measurements of pilot performance as well as opinion for a systematic assessment of the effects of multiple axis degradations.

The pilot performance data obtained from the moving-base simulation (Appendix B) are briefly analyzed in this Appendix to gain some insight into pilot behavior during the HUD tracking task. The HUD tracking evaluation task used in the experiment was constructed to enable the measurement of open-loop pilot/vehicle (Y_pY_c) describing functions.

Two approaches are taken in this Appendix to evaluate pilot behavior in the tracking task. The first involves the use of the "one-third law" which is based on the pilot/vehicle crossover law (Ref. C-1). This was used to provide a quick assessment of whether the pilots were acting in a manner described by the crossover law. The second approach was to extract transfer function models of the pilot using the open-loop pilot/vehicle describing functions.

A. ASSESSMENT OF PILOT ADHERENCE TO THE CROSSOVER LAW

The fundamental theory governing pilot behavior in a closed-loop compensatory tracking task is outlined in Ref. C-1. This theory states that the human operator will, under most conditions, compensate so that the amplitude ratio of the combined pilot/vehicle open-loop dynamics (Y_pY_c) is similar in appearance to that of a simple integrator (k/s) in the frequency region of control. This condition is also one that satisfies the requirements of any good feedback control system. The human operator therefore acts as any good feedback control system would in order to satisfy task performance requirements.

Several basic "rules of thumb" have been developed in Ref. C-1 to describe the performance of a human operator in a closed-loop compensatory tracking task. The "one-third law" is one of these rules and is based on

the following assumptions: 1) the input bandwidth (ω_i) is much less than the pilot/vehicle crossover frequency (ω_c); 2) relatively small remnant or noise is present in the control loop; 3) the input spectrum is rectangular; and 4) $Y_pY_c = \omega_c e^{-\tau_e s}/s$. The one-third law is stated below.

$$\frac{\overline{e^2}}{\sigma_i^2} \approx \frac{1}{3}\left(\frac{\omega_i}{\omega_c}\right)^2 \qquad \text{Eq. C-1}$$

where,

σ_i^2 - variance of the input.

$\overline{e^2}$ - variance of the tracking error.

ω_i - input bandwidth.

ω_c - pilot/vehicle crossover frequency.

The input bandwidth can be estimated through the formula shown below (from Ref. C-1).

$$\omega_i \approx \frac{\left[\int_0^\infty \Phi_{ii}(\omega)d\omega\right]^2}{\int_0^\infty [\Phi_{ii}(\omega)]^2 d\omega} \qquad \text{Eq. C-2}$$

where Φ_{ii} is the input power spectral density.

Application of a discretized Eq. C-2 to the pitch and roll sum-of-sines disturbance inputs (Appendix B) yielded pitch and roll input bandwidths of approximately 1.4 rad/s and 1.8 rad/s, respectively. Since the input variances of the pitch and roll disturbance functions are known (Appendix B), the following "customized" versions of the one-third law were derived for the pitch and roll axes.

Pitch: $$e_\theta \approx \frac{2.16}{\omega_{c_\theta}} \qquad \text{Eq. C-3}$$

Roll: $$e_\phi \approx \frac{10.8}{\omega_{c_\phi}} \qquad \text{Eq. C-4}$$

Plots of $1/\omega_{c_\theta}$ versus e_θ for single-, dual-, and three-axis evaluations are shown in Fig. C-1. The data shown on Fig. C-1 are those for the last evaluation run for a configuration: experimental protocol required that at least two runs be performed per configuration, and the last run per configuration was chosen for this analysis to maximize the likelihood of consistent pilot behavior throughout the tracking run. This philosophy was adopted for all the data analyzed in this Appendix.

Both the one-third law line (Eq. C-3) and a modified one-third law line with a non-zero intercept are shown on all the plots in Fig. C-1. It can be seen that the modified one-third law line describes the trend in the data extremely well. Except for the cases with high $1/\omega_{c_\theta}$ and relatively low e_θ (shown encircled), most data scatter can be described by minor adjustments to the intercept of the one-third law line. The existence of an intercept (which implies that zero rms tracking error is unattainable) is due to the remnant created by the pilots (i.e., the pilots, unlike a linear element, will generate "noise" at frequencies other than those input by the disturbance inputs). The pilot-created remnant can be expected to be different for each pilot and is the probable cause of the data scatter seen in the figures (particularly in Fig. C-1b).

The cases shown encircled in Fig. C-1 can be explained by a phenomenon described as "crossover regression" (Ref. C-1). Crossover regression occurs when a pilot is forced to minimize control inputs in order to maintain tracking error at a reasonable level. Among the factors contributing to this phenomenon was a high disturbance input bandwidth (relative to the pilot/vehicle crossover frequency), combined with adverse vehicle dynamics. As noted in the plots of Fig. C-1, most of the pitch configurations in the encircled regions are LAMARS Cases 5 and 6 (Appendix B) which had identical, very lightly damped and therefore oscillatory, short-period modes which caused the pilots to "back off" on their inputs and avoid exciting the short-period mode. The overall pilot/vehicle dynamics in the vicinity of the crossover frequency for these cases remained k/s in form as was observed from the open-loop describing functions.

The addition of extra axes of control increased the tendency of the pilots to regress in the pitch axis. This is clearly seen in the data for

the combined pitch/roll task (Fig. C-1b). The crossover regression cases in Fig. C-1b span both good (LAMARS Case H) and bad (LAMARS case C) roll dynamics, indicating that the low-damped pitch dynamics in these configurations can only be used somewhat satisfactorily for closed-loop tracking in a single axis (pitch).

The combined pitch/airspeed tracking task proved to be somewhat distracting and unnatural to the pilots due to conflicting pitch and airspeed cues. As a result, this task was not evaluated extensively. Insufficient data existed (Fig. C-1c) to enable any conclusions to be drawn on the effect of the airspeed tracking on pitch axis performance.

Plots of $1/\omega_{c_\phi}$ versus e_ϕ for single-, dual-, and three-axis tracking evaluations are shown in Fig. C-2. The LAMARS Case identifiers for the configurations for some of the data are also shown in Fig. C-2. Single- and pitch/roll dual-axis data are shown separately for each pilot to illustrate the differences between pilots. The one-third law line (Eq. C-4) is shown on all plots. The single axis evaluation data for pilot M (Fig. C-2a), and to a lesser extent pilots H and S (Fig. C-2b), are seen to correlate the one-third law extremely well. The correlation with the one-third law for the other pilots for both single- and dual-axis evaluations is not as good. Increased pilot remnant by pilots B and V may be the cause for the relatively large rms tracking errors seen in Figs. C-2c and C-2d. Inspection of the Y_pY_c describing functions for these pilots indicated that they conformed with the crossover law in the region of the crossover frequency.

The roll-axis Y_pY_c describing functions for a sample of runs and configurations were inspected in an effort to identify the causes of the inter-pilot variation in roll-axis performance. Typical open-loop Y_pY_c describing functions for LAMARS Case C for pilots M, B, and V are shown in Fig. C-3. The amplitude ratios of Y_pY_c for all three pilots approximate the k/s line, also shown in Fig. C-3. These data indicate that pilot M may have had greater phase margin, which would have contributed to his better performance with this configuration. The primary cause of this inter-pilot variation, however, is probably pilot-induced remnant.

Some evidence of crossover regression in the roll axis can be seen in the dual-axis data for pilot M (Fig. C-2e) and three-axis data for all pilots (Fig. C-2j). The three-axis data are heavily weighted by pilot M, who performed the majority of the three-axis evaluations.

Preliminary evaluation of the pilot performance data in the tracking task therefore indicates that the pilots did perform as predicted by the human-pilot crossover law (Ref. C-1). This was especially true in the pitch axis, where pilot remnant was relatively low when compared with the roll axis.

B. PILOT MODEL ANALYSIS

A complete listing of all the open-loop pilot/vehicle (Y_pY_c) describing functions for the moving-base simulation is provided in Appendix B. Since the controlled element Y_c is known for all configurations, a model of the pilot behavior Y_p can be extracted by matching a transfer function model with the Y_pY_c describing function data.

A complete evaluation of all the describing function data was desireable but not feasible due to time and budget constraints. In order to evaluate the effect of added axes of control on pilot behavior, the analysis reported herein concentrated on the results for pilot M,who evaluated the most complete matrix of configurations in single-, dual- (various combinations) and three-axis HUD tracking task runs. The analysis was also restricted to the configurations with dynamics similar to regular fixed-wing aircraft (LAMARS Cases 2, 4, 5, and 6 in pitch and H, B,and C in roll; Appendix B).

The procedure for extracting pilot models involved the fitting of a transfer function model to the Y_pY_c describing function data. Best performance runs for pilot M (lowest rms tracking error(s)) were chosen for the analysis for cases where repeat runs existed. The transfer function form of Y_pY_c to be fitted to the data included the known controlled element dynamics (Y_c) and an assumed form for the pilot dynamics (Y_p). The assumed form for Y_p (shown below) consisted of a gain, a lead-lag, and a time delay to account for all pilot high-frequency lags, including neuromuscular dynamics.

$$Y_p = \frac{K_p(T_{lead}s + 1)\, e^{-\tau_p s}}{(T_{lag}s + 1)}$$

Fitting of the Y_pY_c transfer function amplitude ratio and phase to the describing function data was performed by in-house optimizing software (Program MFP, Ref. C-2). All elements in the assumed pilot model were allowed to vary.

The extracted pilot models for pilot M are listed in Table C-1. Comparisons of the fitted Y_pY_c model with the describing function data together with run identifiers (Appendix B) for the runs analyzed are presented in Figures C-4 through C-9, where the describing function data are shown as symbols (○ - amplitude ratio, □-phase) and the model as lines (continuous - amplitude ratio, dashed - phase). The model compares favorably with the data in the majority of the cases, with the exception of a few pitch-axis configurations (Cases 5 and 6).

The single-axis, longitudinal pilot models (Y_{p_θ}) in Table C-1 show that the pilot consistently applied lag equalization in the vicinity of the airframe lead ($1/T_{\theta_2}$ = 1.25 rad/s) to extend the region of k/s in the open-loop pilot/vehicle (Y_pY_c), and thereby obtain a higher crossover frequency. Higher crossover frequencies will, in general, result in improved tracking performance, provided there is sufficient phase margin. For the configurations with good short-period damping (Cases 2 and 4), the pilot was able to also apply some lead equalization to improve phase margins and further increase the open-loop Y_pY_c crossover frequency. Lead equalization was not possible for the low-damped configurations (Cases 5 and 6) due to the high amplitude ratio peak in the controlled element which reduced the available gain margins. The lack of pilot time delay in the single- and dual-axis models for Case 6 is probably due to the scatter in the higher frequency describing function data.

No consistent trends were seen in the pitch pilot models with the addition of workload in the other axes (Table C-1). The pilot dynamics (Y_{p_θ}) remained the same as they were for pitch single-axis evaluations. There were,however, changes in pilot gain with accompanying variations in

crossover frequency with the addition of other axes to the task, as noted in the main text of this report

The pilot models in the roll axis (Y_{p_ϕ}) are also shown in Table C-1. The single-axis models show that the pilot attempted to equalize the lag due to the roll mode ($1/T_R$) by providing lead compensation. This proved somewhat difficult for Cases B and C due to the low frequency at which the lead must be placed. Equalization of the roll mode provided the greater region of k/s in Y_pY_c, which is necessary for good performance. The values for pilot time delay were significantly higher than observed in the pitch-axis models. This is probably due to the effect of the pilot's arm/bobweight or neuromuscular dynamics, which are usually situated in the 10 to 15 rad/s frequency region.

The addition of pitch axis workload consistently degrades pilot M's capability to equalize the roll mode. This is clearly seen with Case H (Table C-1). Interestingly, the addition of the airspeed tracking task (using throttle) alone does not have a significant effect on the pilot's behavior. Pilot models for the three-axis evaluations show all equalization in the roll axis (Y_{p_ϕ}) to be at low frequency. This is an indication that the pilot regressed in the roll axis and was satisfied with a lower crossover frequency in a probable attempt to cope with the total workload (evidence for this effect in the roll axis for the three axis evaluations is also shown in the previous section in this Appendix).

Pilot models for pilot M therefore indicate that he reallocated his priorities in dual pitch/roll tracking in favor of the pitch axis. This is seen in his pitch dynamics (Y_{p_θ}), where no significant change in his dynamics are observed with the addition of workload in the roll axis, and in his roll dynamics (Y_{p_ϕ}), where a consistent degradation is observed in his dynamics with the addition of pitch-axis workload.

REFERENCES

C-1. McRuer, D. T., and E. S. Krendel, Mathematical Models of Human Pilot Behavior, AGARD-AG-188, Jan. 1974.

C-2. DiMarco, Richard J., and Raymond E. Magdaleno, "User's Manual for Multi-Input Frequency Response Identification Program," Systems Technology, Inc., WP-407-7, Dec. 1984.

TABLE C-1 PILOT MODELS

a) Pitch Axis

		LAMARS CASE			
		2	4	5	6
Controlled Element Y_{c_θ}		$\frac{(1.25)e^{-0.033s}}{(0)\ [0.8;\ 5.0]}$	$\frac{(1.25)e^{-0.2s}}{(0)\ [0.8;\ 5.0]}$	$\frac{(1.25)e^{-0.033s}}{(0)\ [0.18;\ 5.0]}$	$\frac{(1.25)e^{-0.2s}}{(0)\ [0.18;\ 5.0]}$
Single Axis Y_{p_θ}		$\frac{22.3\ (2.8)e^{-0.132s}}{(1.18)}$	$\frac{19.0\ (1.75)e^{-0.086s}}{(1.02)}$	$\frac{2.6\ (11.0)e^{-0.081s}}{(0.69)}$	$\frac{21.8}{(0.93)}$
Dual Axis Y_{p_θ}	with Roll H	$\frac{16.3\ (3.7)e^{-0.128s}}{(1.25)}$	$\frac{4.8\ (10.4)}{(1.0)}$	$\frac{38.5\ e^{-0.01s}}{(1.22)}$	$\frac{24.6}{(0.90)}$
	with Roll B	$\frac{18.0\ (3.32)e^{-0.154s}}{(1.88)}$	—	$\frac{34.6\ e^{-0.03s}}{(1.43)}$	$\frac{24.5}{(0.94)}$
	with Roll C	$\frac{19.0\ (2.36)e^{-0.156s}}{(1.73)}$	$\frac{18.8\ (1.14)e^{-0.09s}}{(0.93)}$	$\frac{37.4\ e^{-0.0176s}}{(1.45)}$	$\frac{3.79\ (2.95)}{(1.26)}$
Dual Axis with T6		$\frac{15.9\ (2.47)e^{-0.152s}}{(0.8)}$	—	$\frac{2.28\ (13.4)e^{-0.089s}}{(1.02)}$	—
Three Axis Y_{p_θ}	with HT6	$\frac{15.0\ (3.0)e^{-0.144s}}{(1.15)}$	—	$\frac{29.6\ e^{-0.028s}}{(1.05)}$	—
	with BT6	$\frac{18.4\ (2.9)e^{-0.158s}}{(1.73)}$	—	—	—

$(a) \equiv (s + a)$

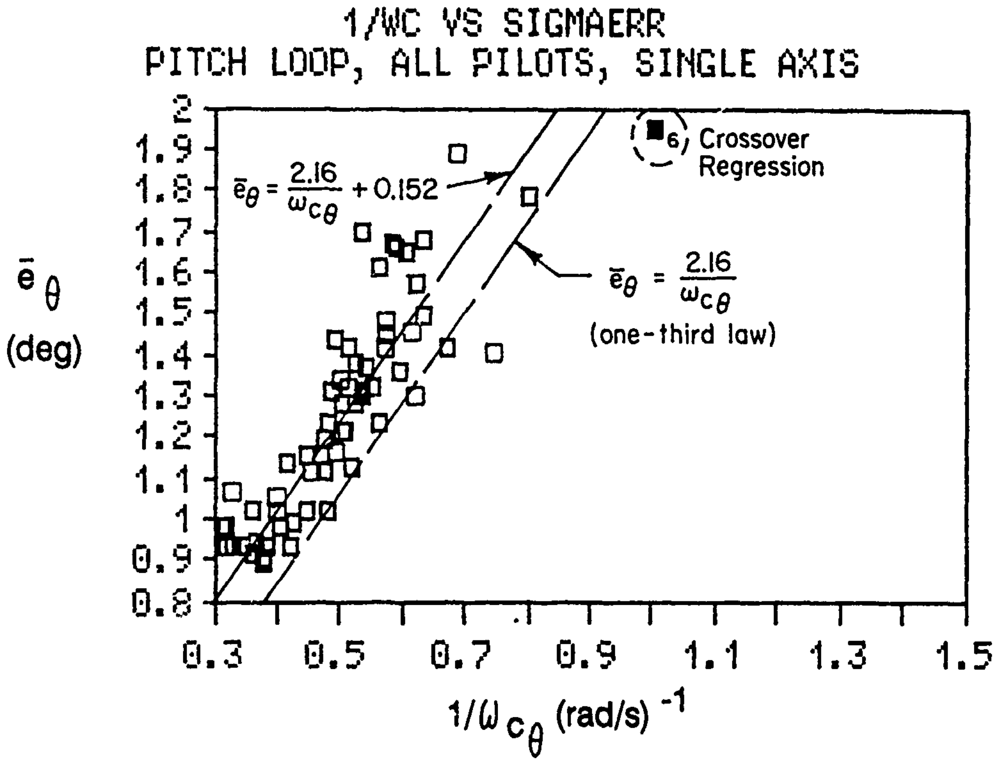
$[\zeta;\omega] \equiv (s^2 + 2\zeta\omega s + \omega^2)$

TABLE C-1 PILOT MODELS (CONCLUDED)

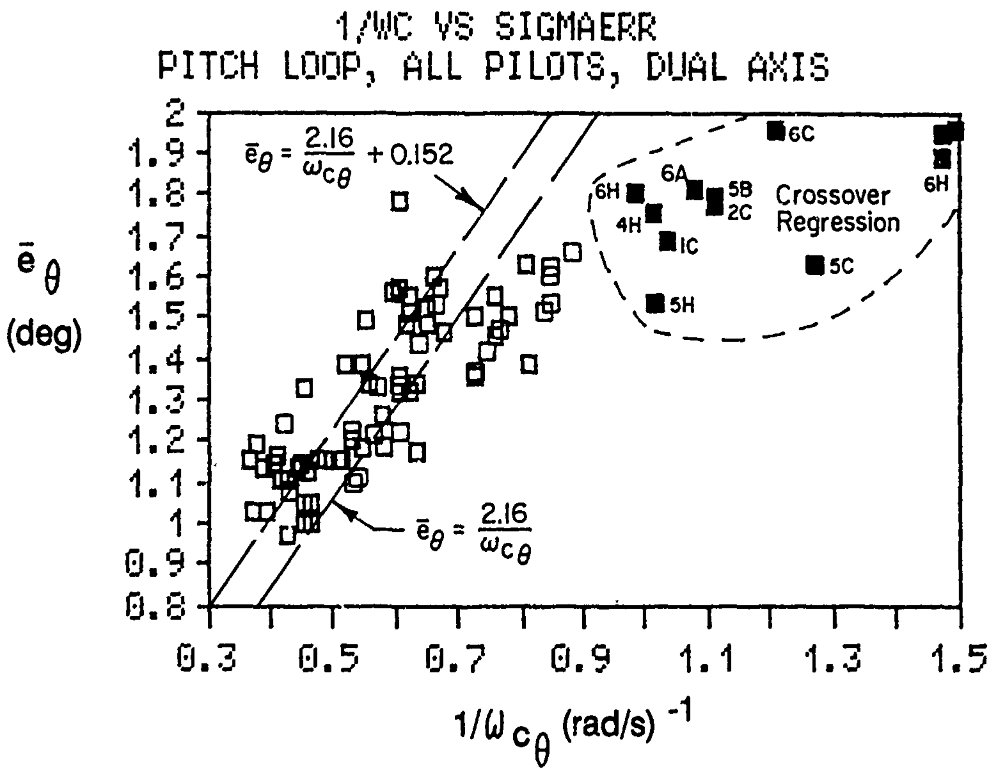
b) Roll Axis

		LAMARS CASE		
		H	B	C
Controlled Element Y_{c_ϕ}		$\frac{1\ e^{-0.067s}}{(0)\ (4.0)}$	$\frac{1\ e^{-0.2s}}{(0)\ (0.5)}$	$\frac{1\ e^{-0.2s}}{(0)\ (0.5)}$
Single Axis Y_{p_ϕ}		$\frac{27.5\ (2.6)e^{-0.265s}}{(10)}$	$\frac{6.8\ (0.02)e^{-0.19s}}{(2.5)}$	$\frac{17.6\ (0.16)e^{-0.312s}}{(13.2)}$
Dual Axis Y_{p_ϕ}	with Pitch 2	$\frac{41.0\ (1.2)e^{-0.356s}}{(12.8)}$	$\frac{6.6\ (0.02)e^{-0.3s}}{(3.53)}$	$\frac{19.4\ (0.02)e^{-0.5s}}{(12.9)}$
	with Pitch 4	$\frac{12.4\ (0.57)e^{-0.322s}}{(3.68)}$	—	$\frac{2.3\ (0.16)e^{-0.21s}}{(1.06)}$
	with Pitch 5	$\frac{10.6\ (0.06)e^{-0.29s}}{(1.67)}$	$\frac{8.52(0)e^{-0.368s}}{(6.76)}$	$\frac{3.9\ (0)e^{-0.29s}}{(3.32)}$
	with Pitch 6	$\frac{10.4\ (0.15)e^{-0.324s}}{(2.67)}$	$\frac{3.0\ (0.02)e^{-0.311s}}{(2.36)}$	$\frac{1.15\ (0.16)e^{-0.251s}}{(0.75)}$
Dual Axis Y_{p_ϕ} with T2 & T6		$\frac{2.1\ (3.17)e^{-0.3s}}{1}$	$\frac{1.52\ (0.02)e^{-0.317s}}{1}$	—
Three Axis Y_{p_ϕ}	with 2T6	$\frac{7.1\ (0.06)e^{-0.245s}}{(0.65)}$	$\frac{12.1\ (0.02)e^{-0.306s}}{(10.8)}$	
	with 5T6	$\frac{6.6\ (0.11)e^{-0.237s}}{(0.98)}$		

$(a) \equiv (s + a)$
$[\zeta;\omega] \equiv (s^2 + 2\zeta\omega s + \omega^2)$

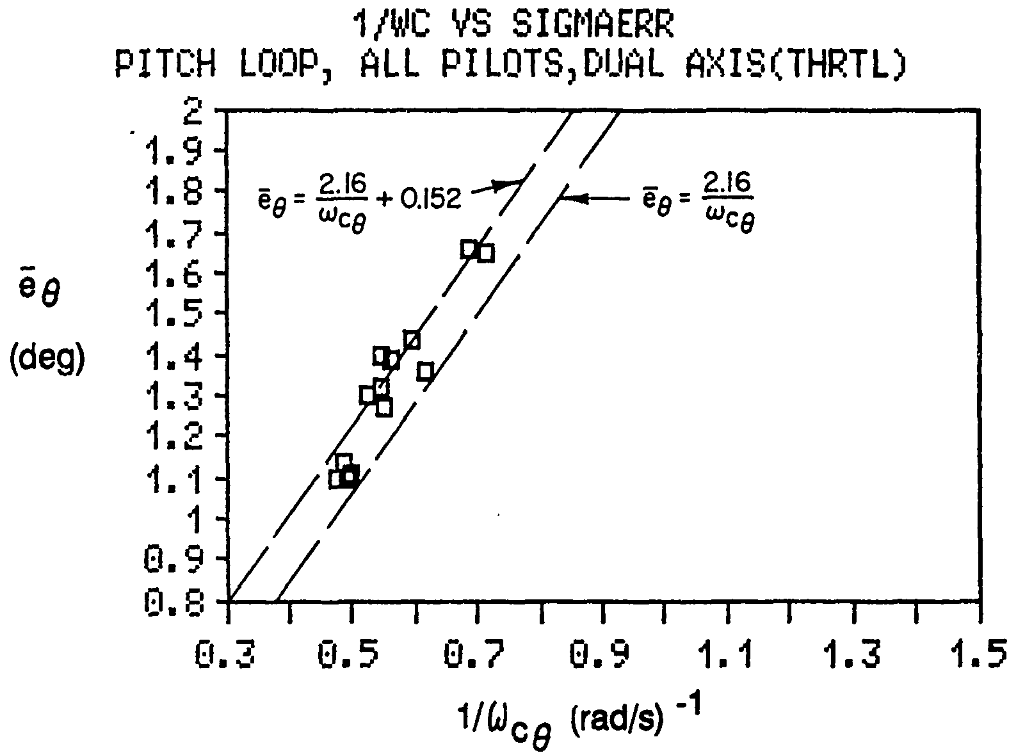


a) Pitch; Single-Axis

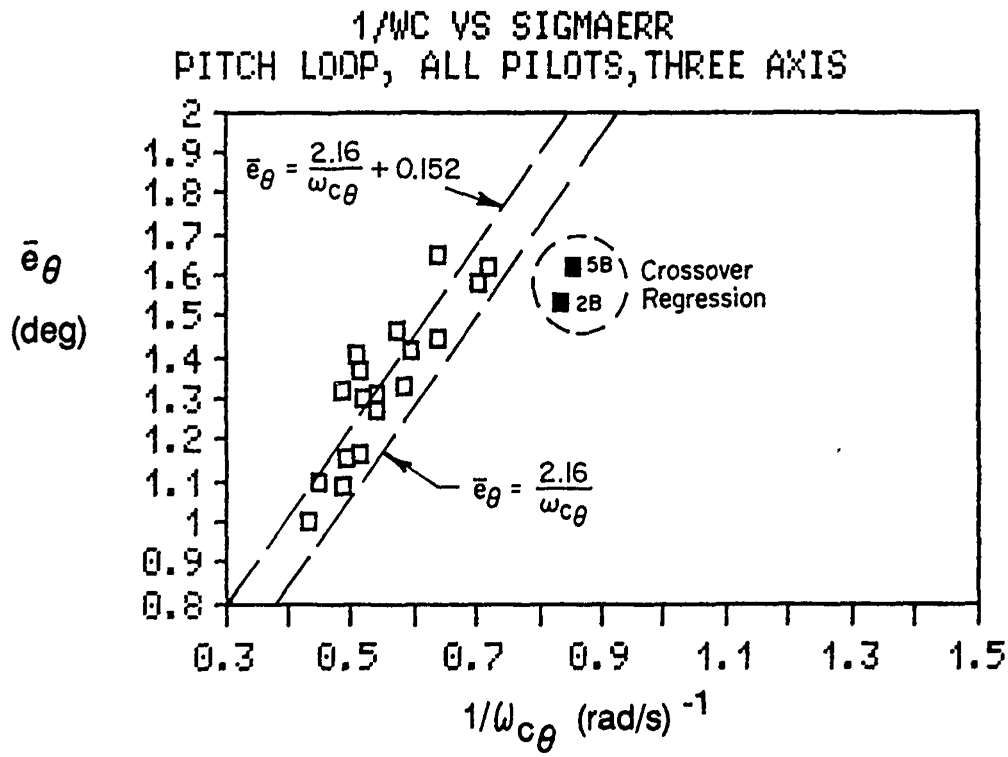


b) Pitch; Dual-Axis (roll)

Figure C-1. Correlation of Tracking Error and Crossover Frequency (Pitch Axis)

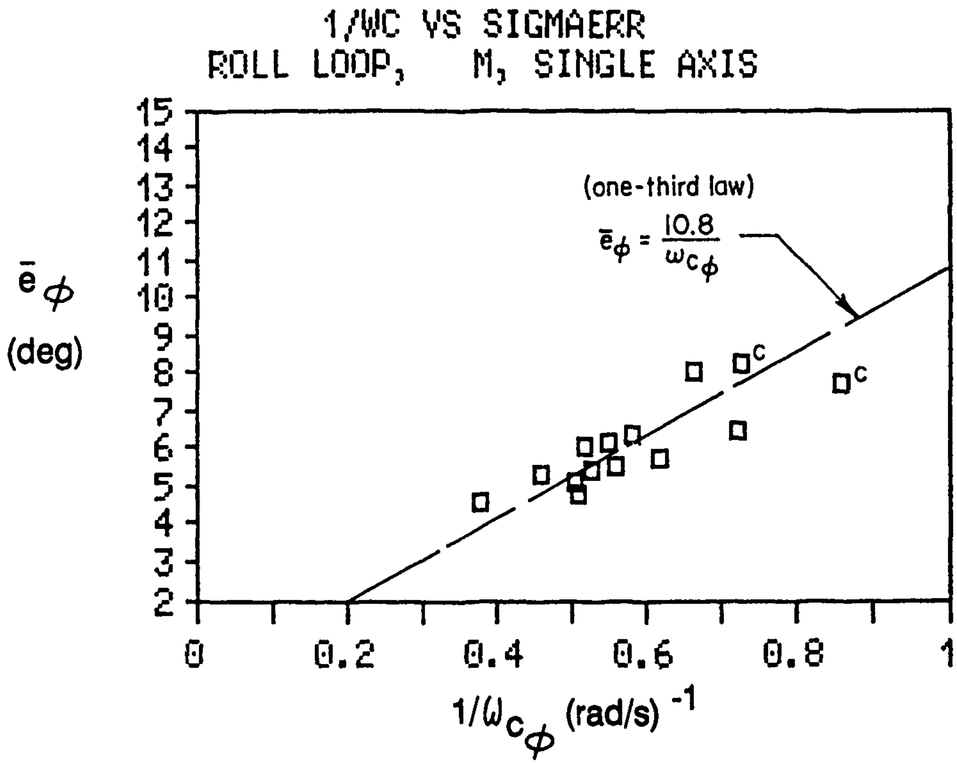


c)Pitch; Dual-Axis (airspeed)

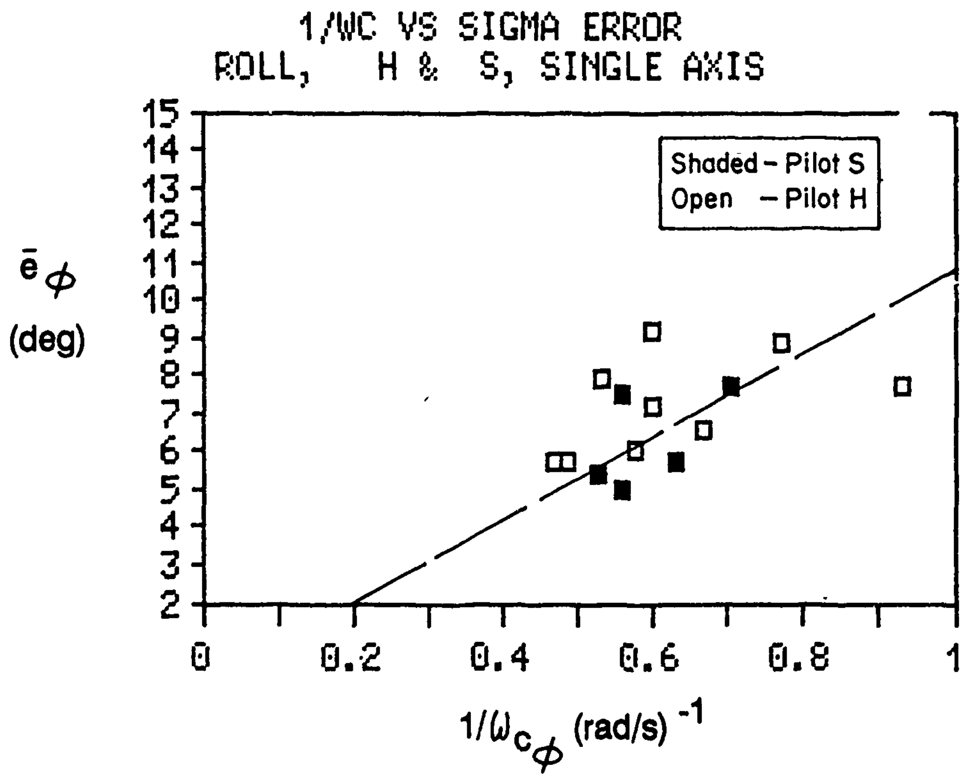


d) Pitch; Three-Axis

Figure C-1. (Concluded)

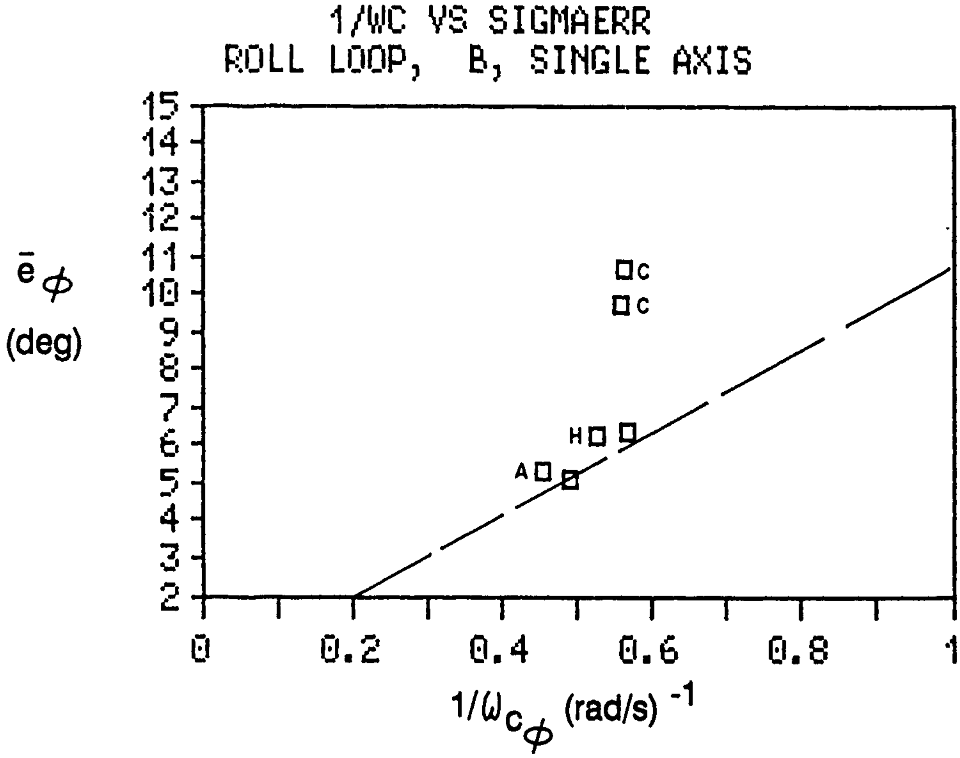


a) Roll; Single-Axis -- Pilot M

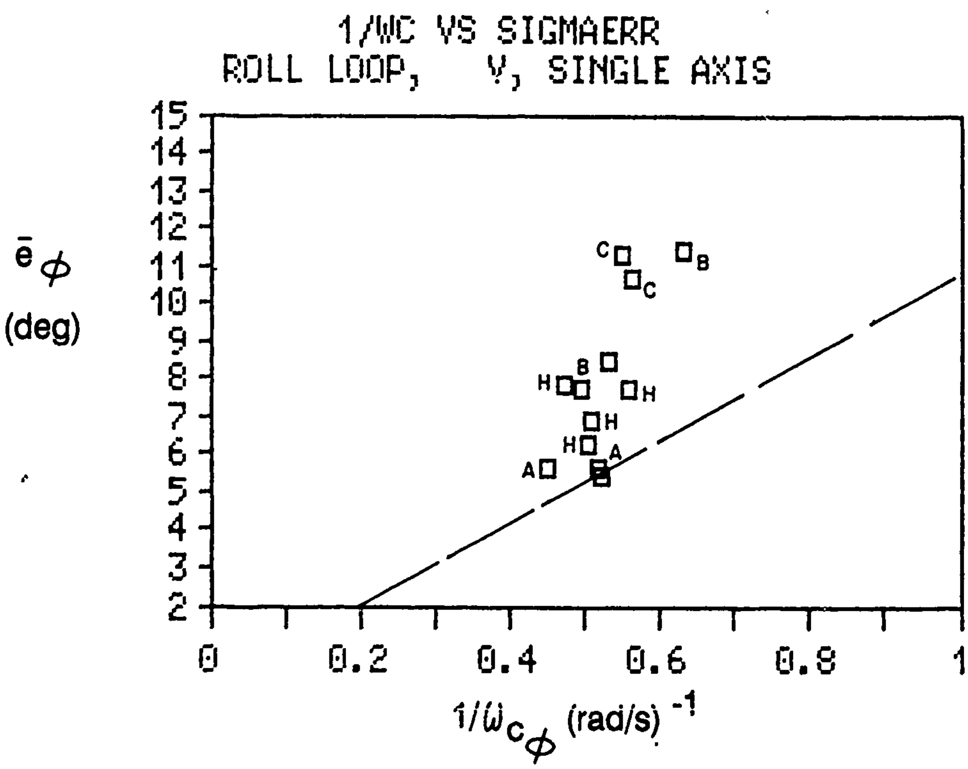


b) Roll; Single-Axis -- Pilots H & S

Figure C-2. Correlation of Tracking Error and Crossover Frequency (Roll Axis)

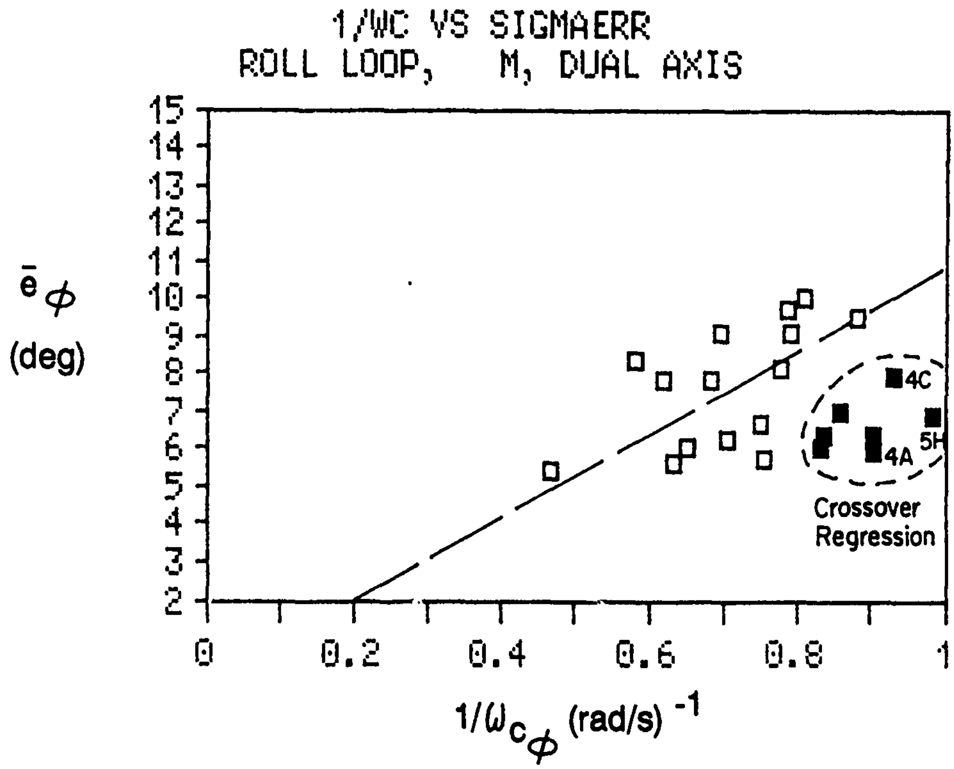


c) Roll; Single-Axis -- Pilot B

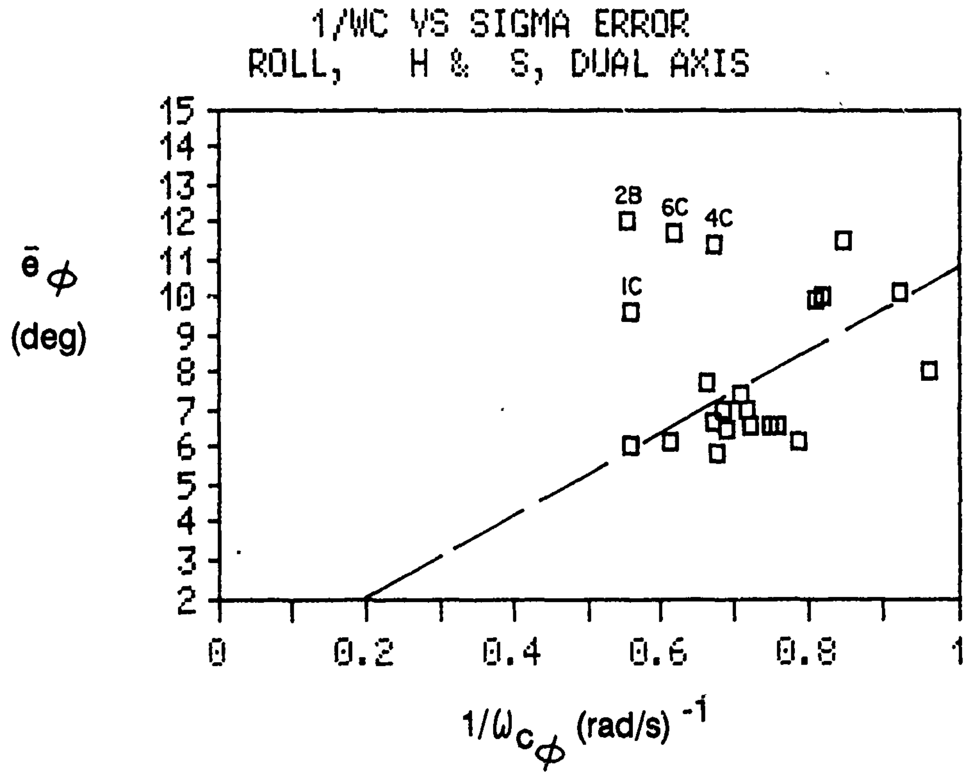


d) Roll; Single-Axis -- Pilot V

Figure C-2. (Continued)

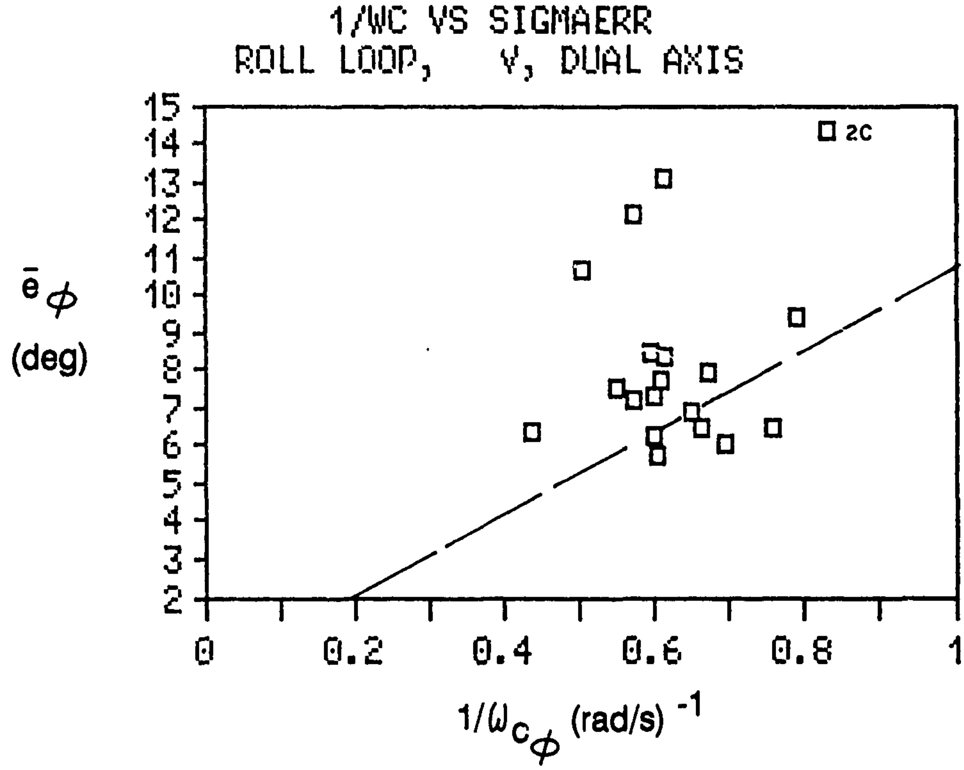


e) Roll; Dual-Axis (pitch) Pilot M

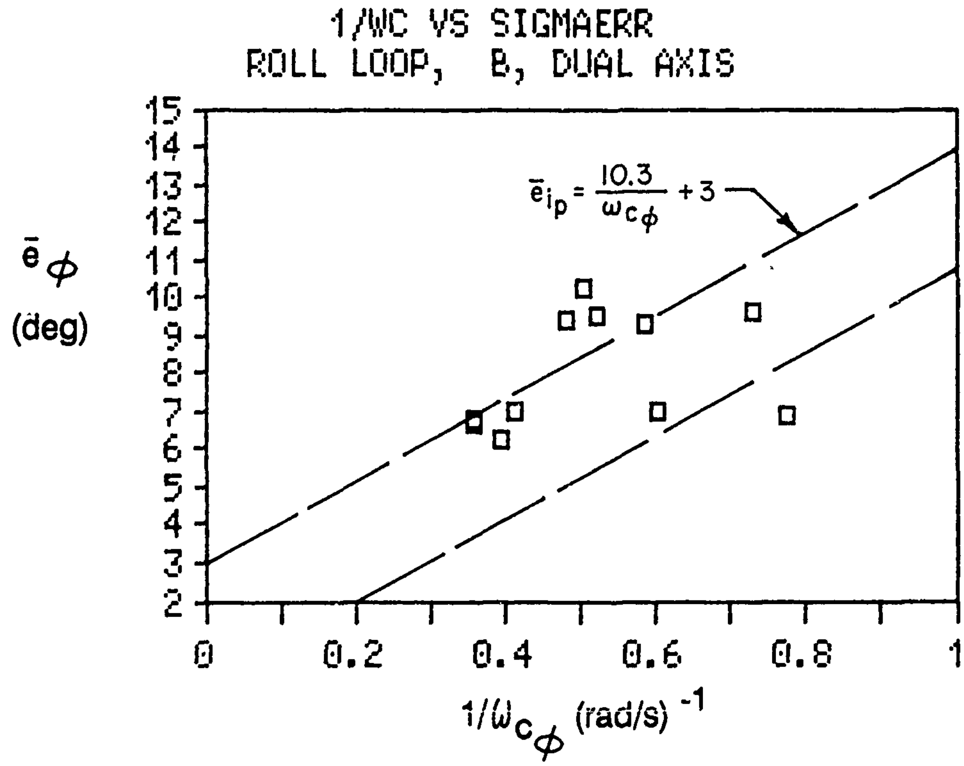


f) Roll; Dual-Axis (pitch) Pilots H & S

Figure C-2. (Continued)

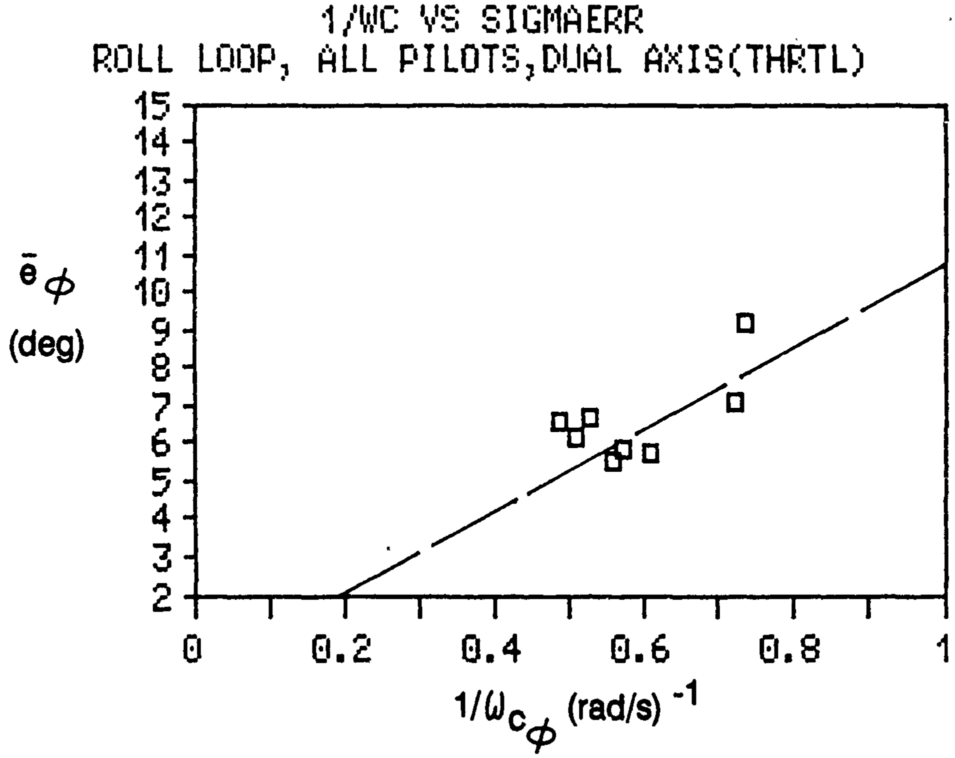


g) Roll; Dual-Axis (pitch) Pilot V

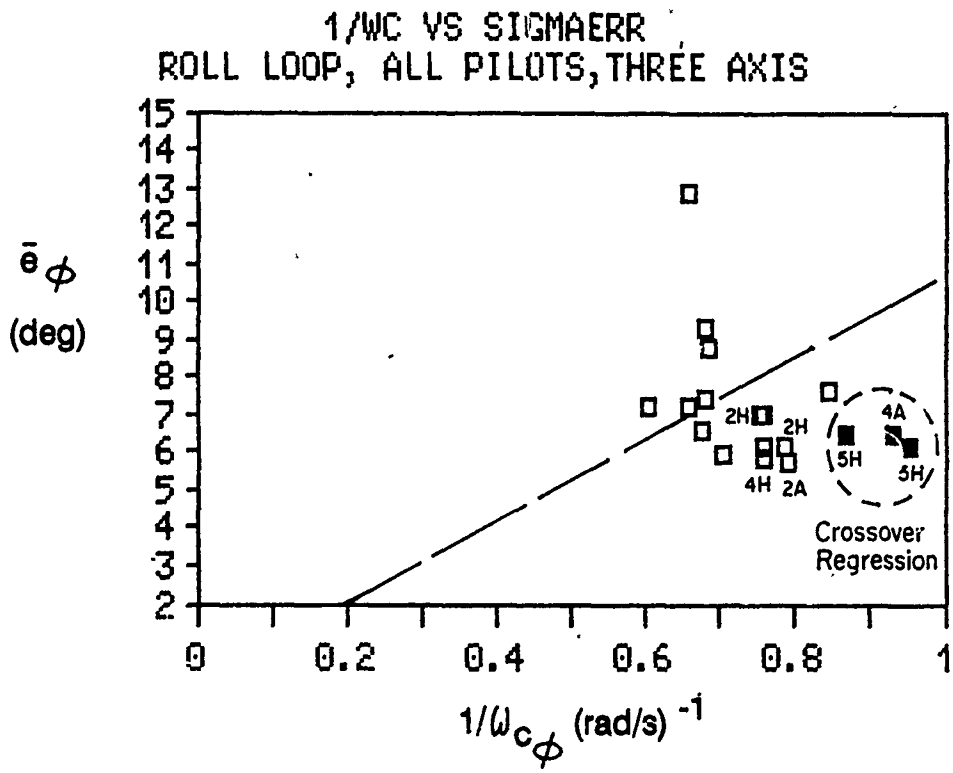


h) Roll; Dual-Axis (pitch) Pilot B

Figure C-2. (Continued)



i) Roll; Dual-Axis (airspeed) Pilots M, V & B



j) Roll; Three-Axis -- Pilot M, V & B

Figure C-2. (Concluded)

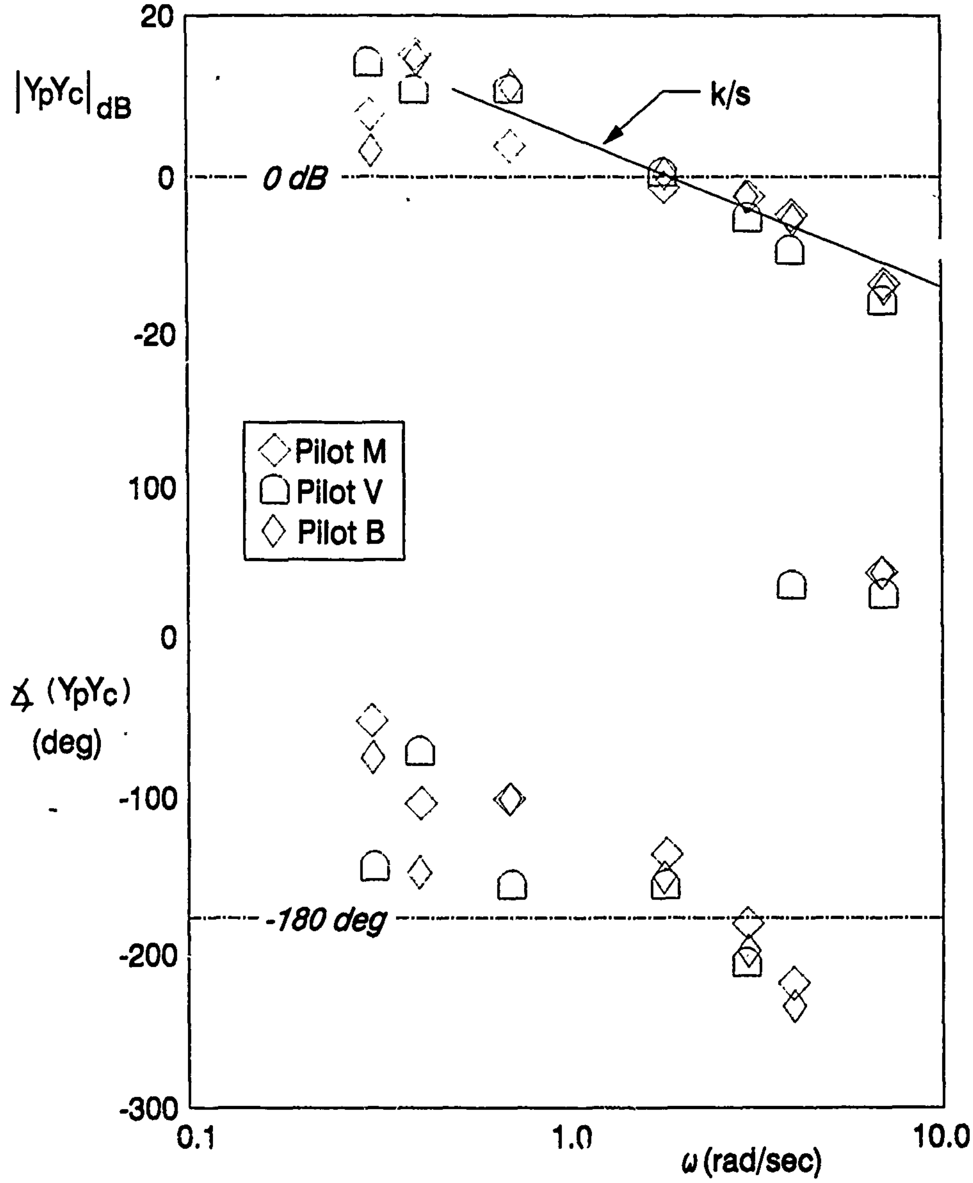
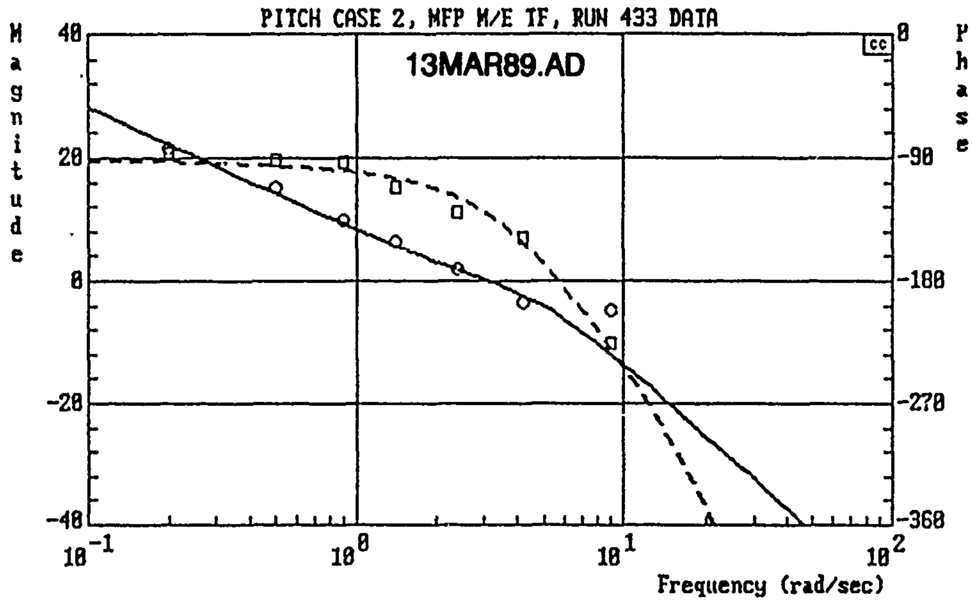


Figure C-3. Y_pY_c for LAMARS Cases C



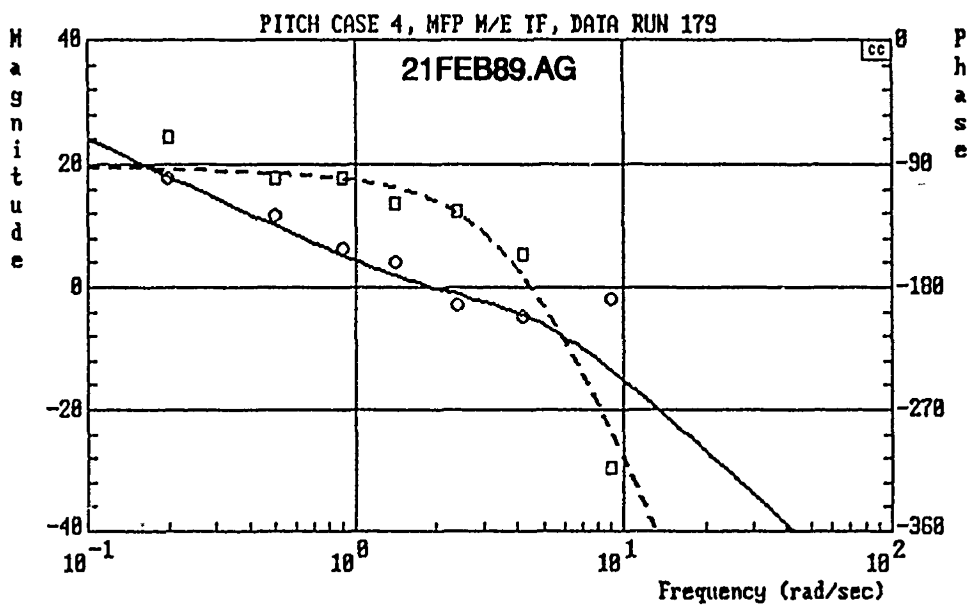
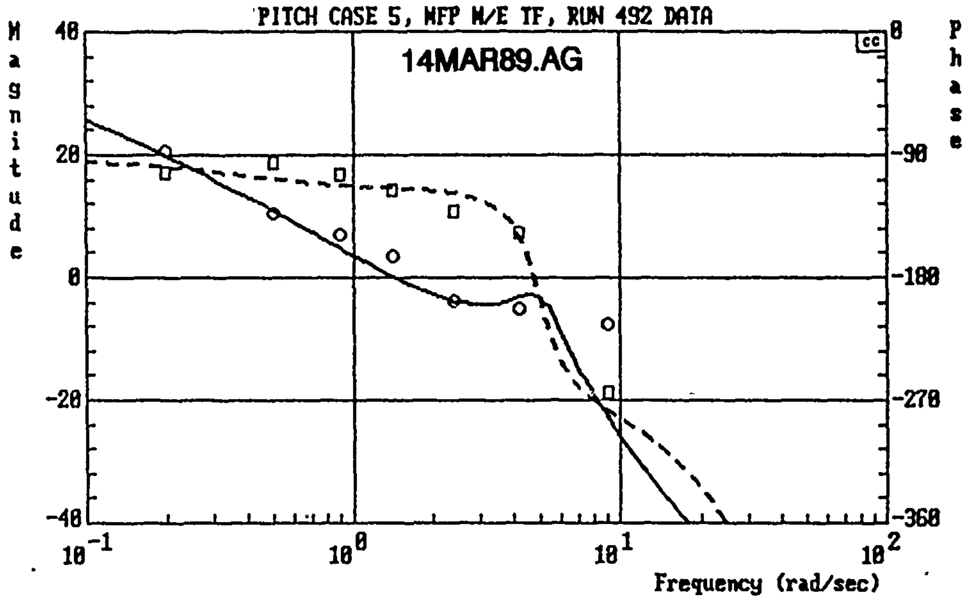


Figure C-4. Y_pY_c Model Versus Data
Pitch - Single-Axis



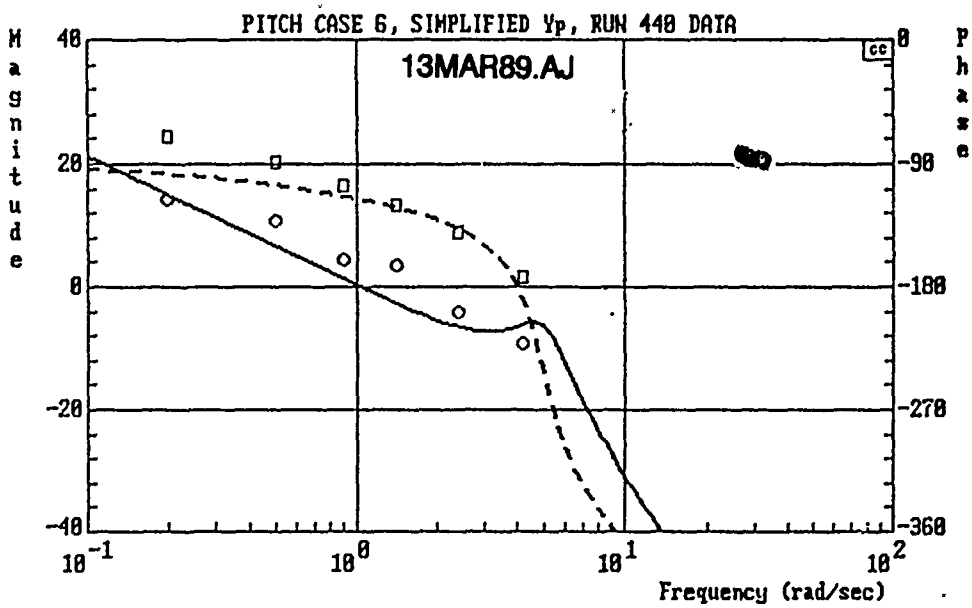
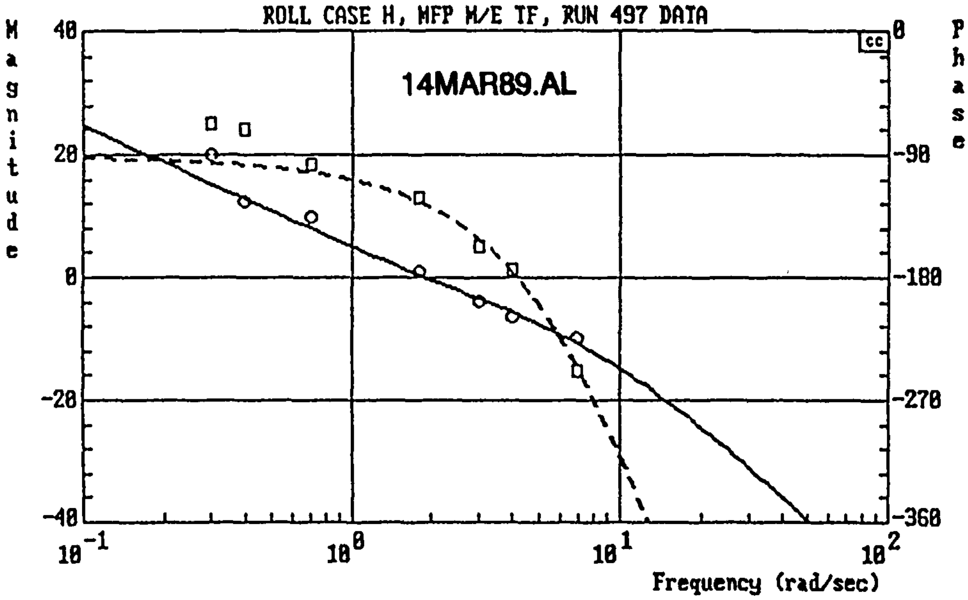


Figure C-4. (Concluded)



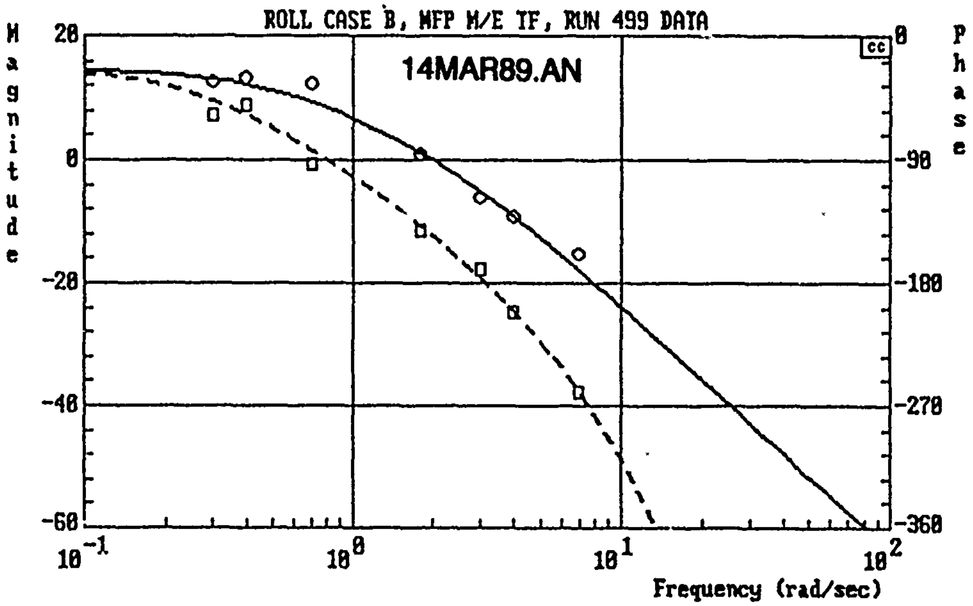


Figure C-5. Y_pY_c Model Versus Data
Roll - Single-Axis

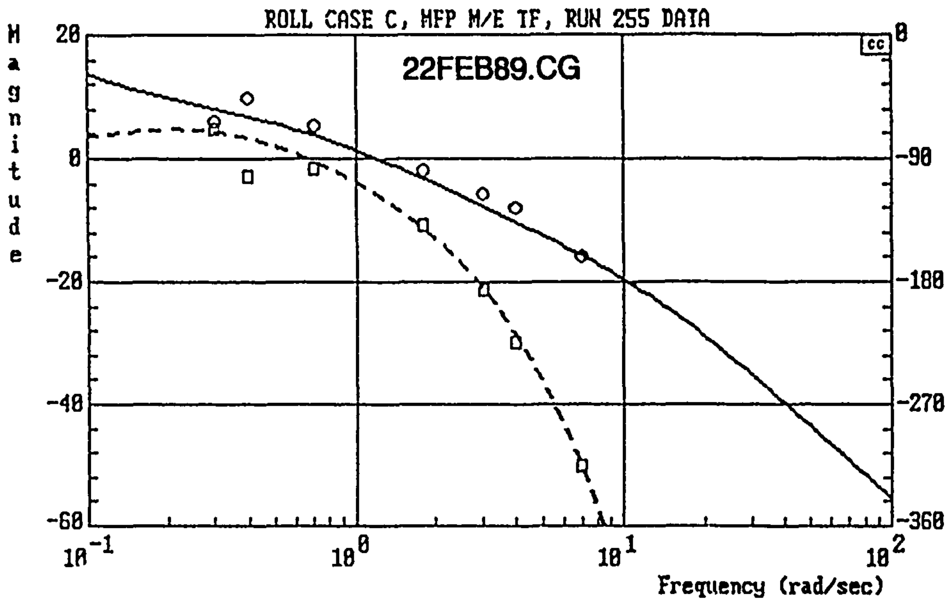
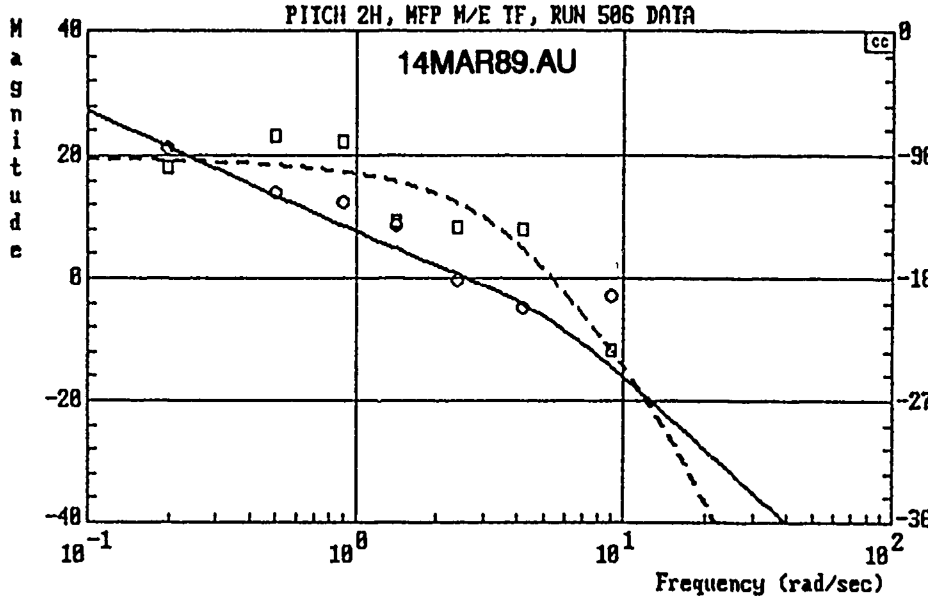


Figure C-5. (Concluded)



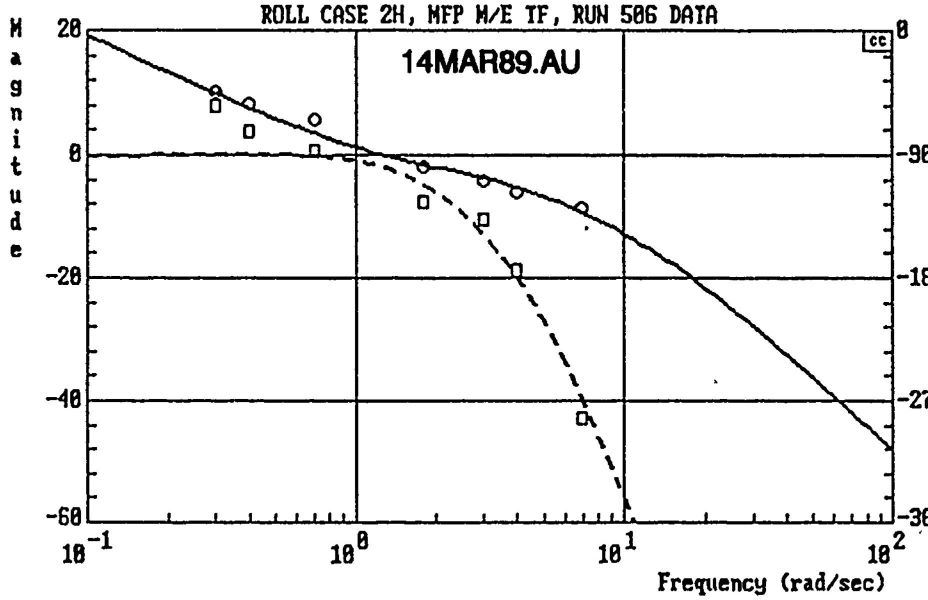
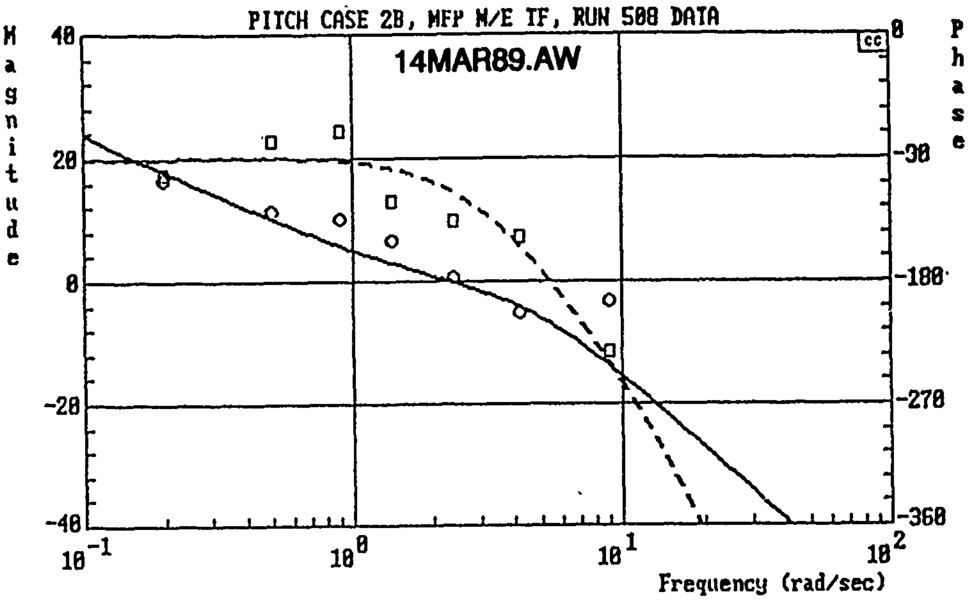


Figure C-6. Y_pY_c Model Versus Data
Pitch/Roll - Dual-Axis



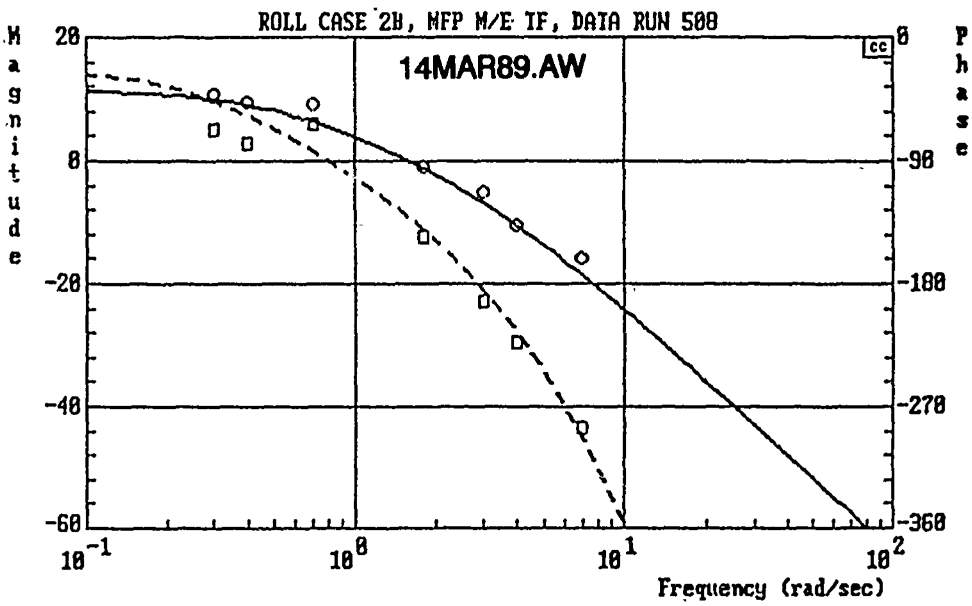
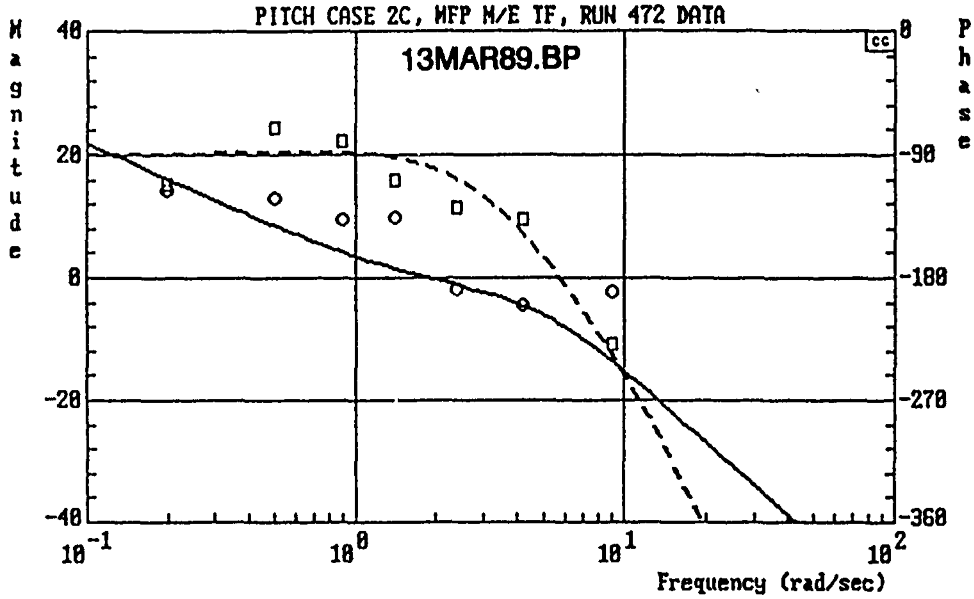
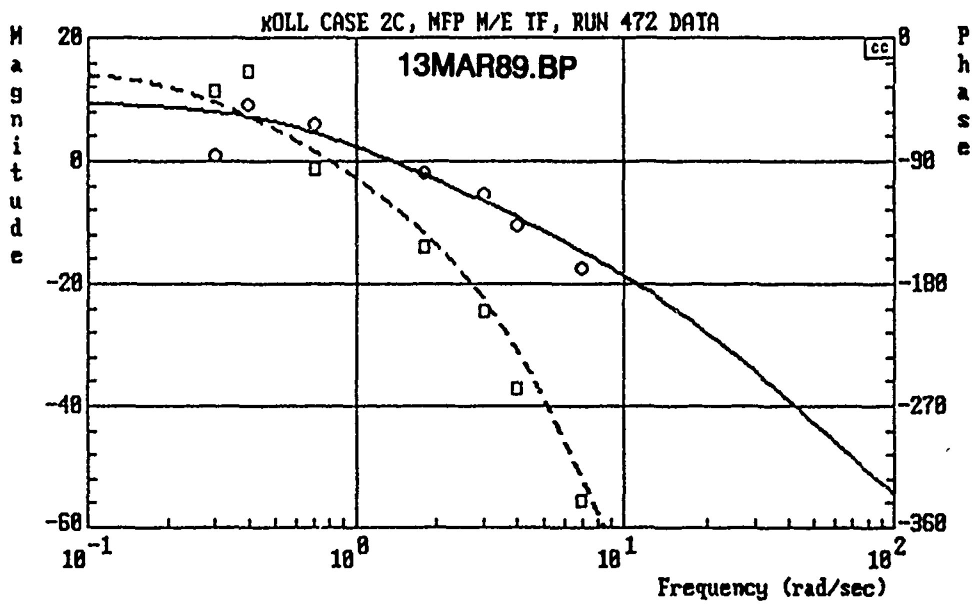


Figure C-6. (Continued)





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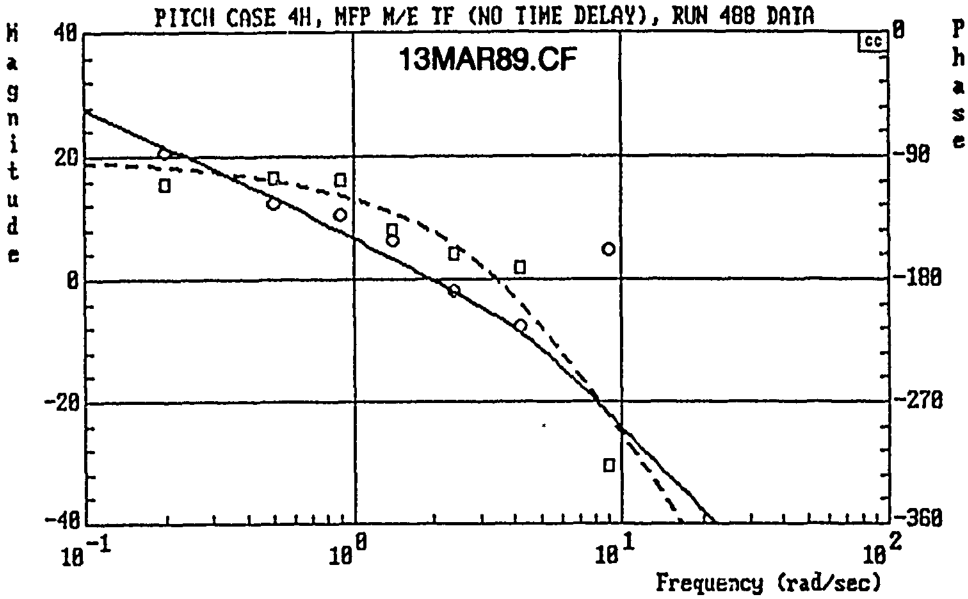


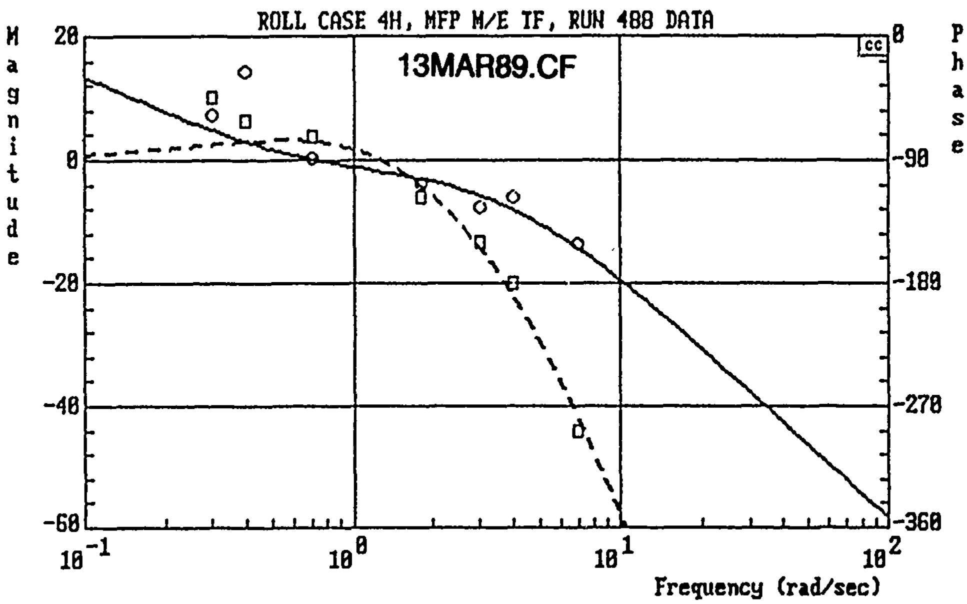
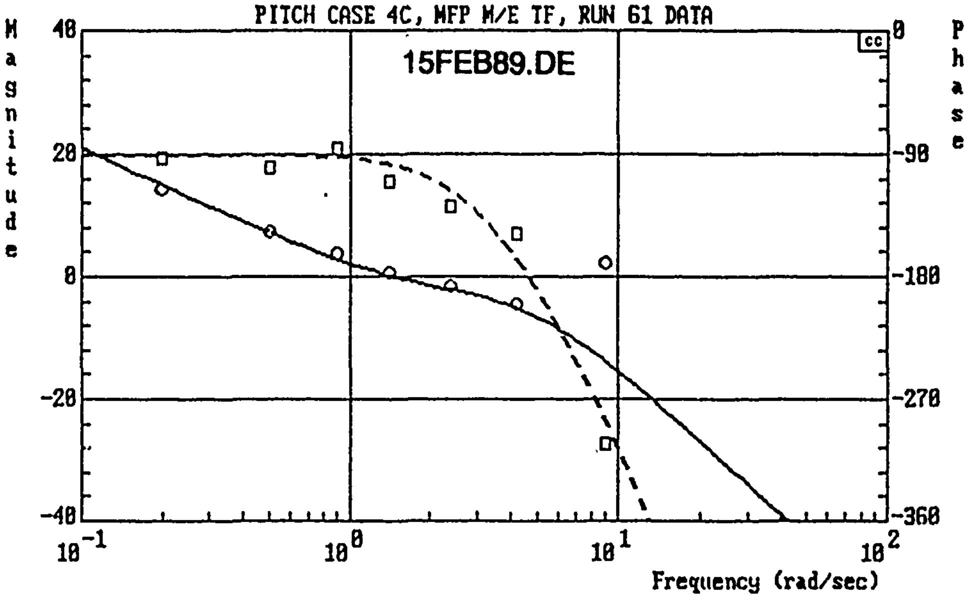


Figure C-6. (Continued)



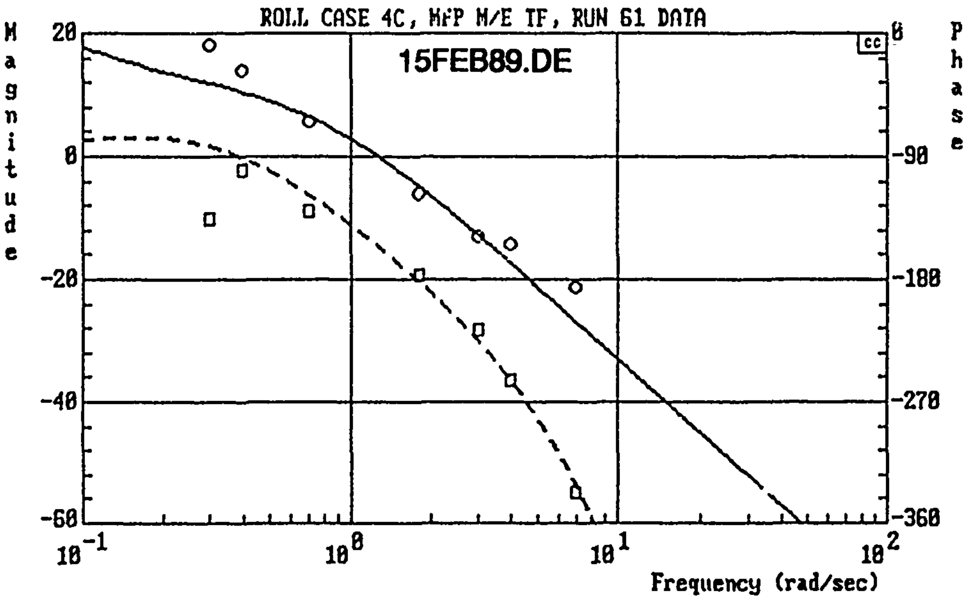
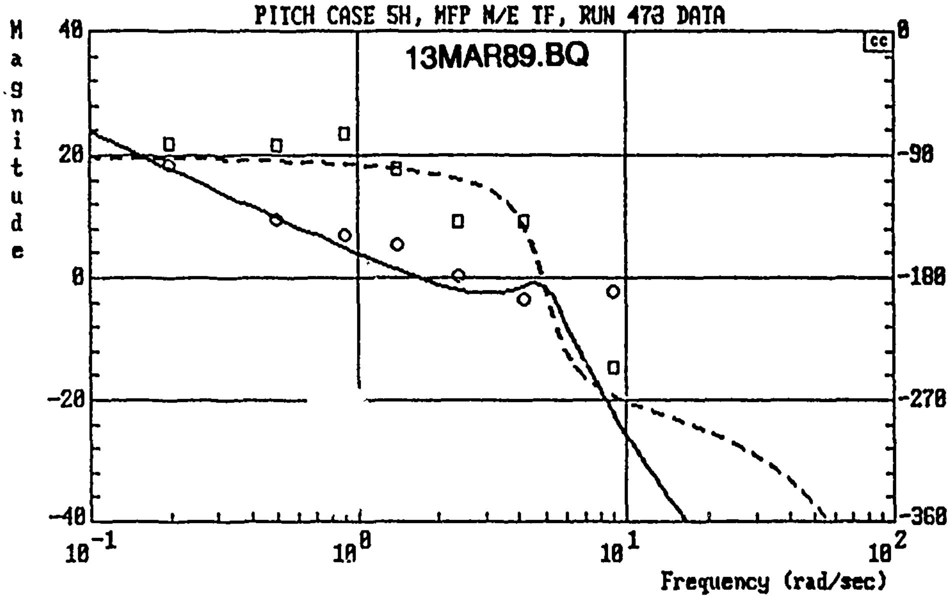


Figure C-6. (Continued)



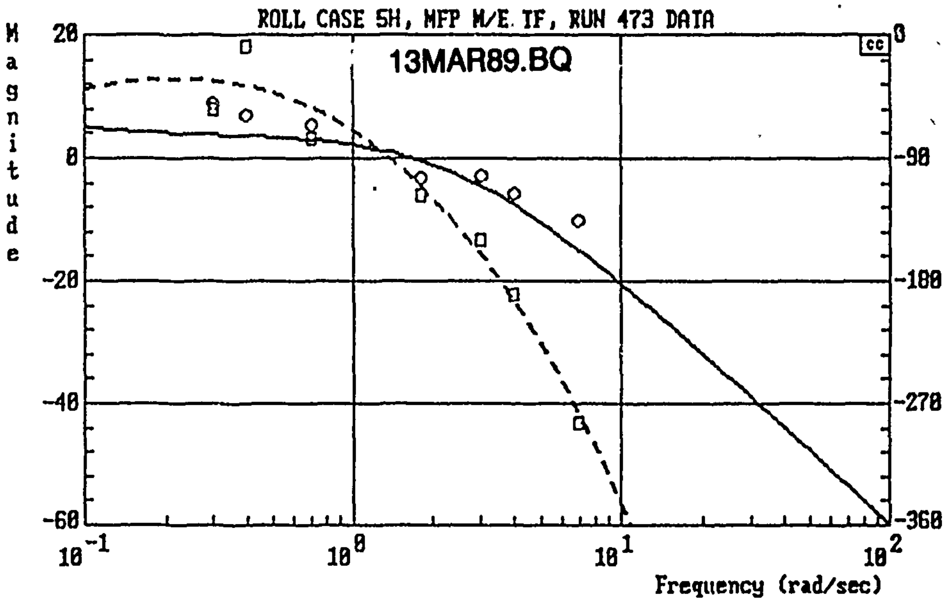
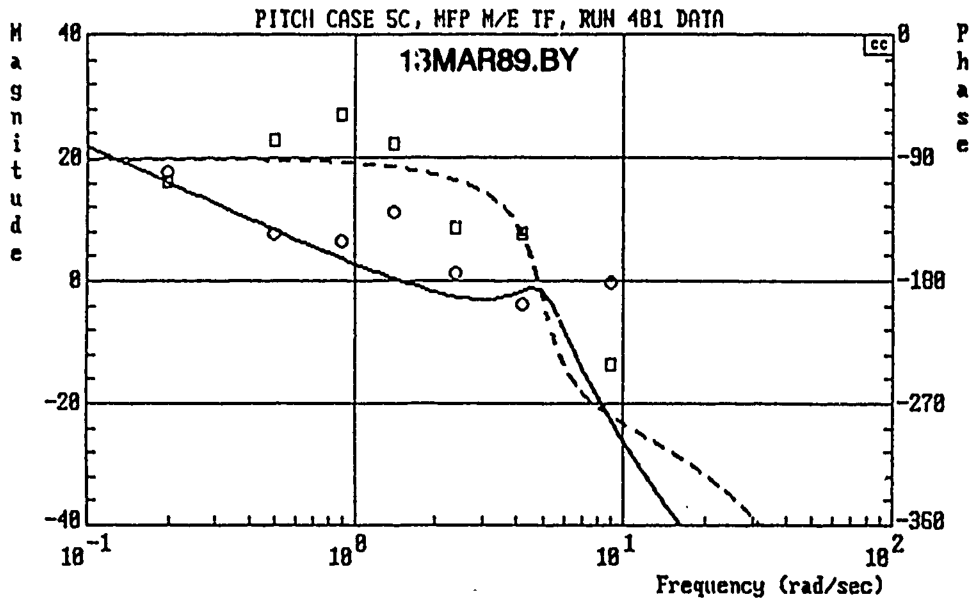


Figure C-6. (Continued)



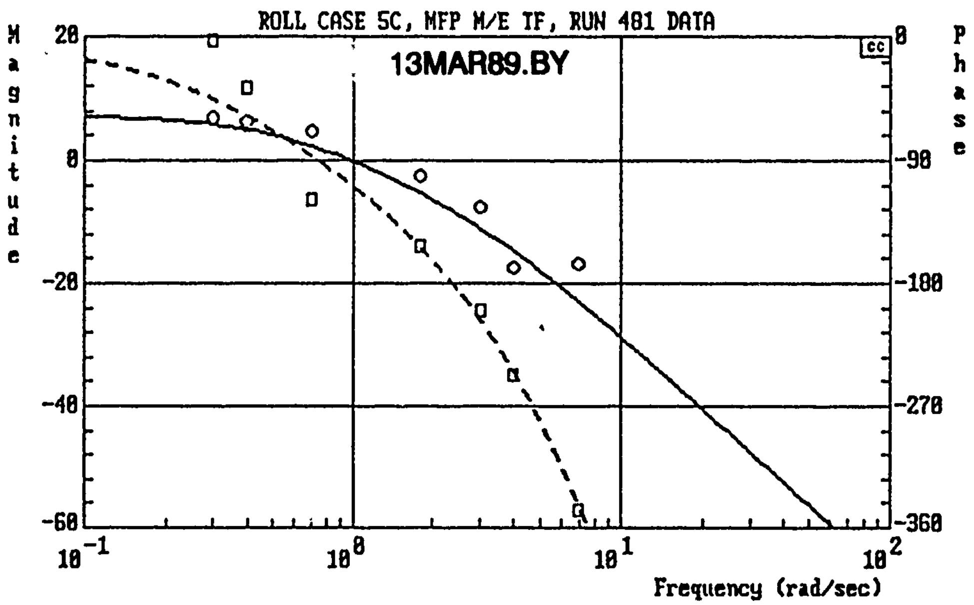
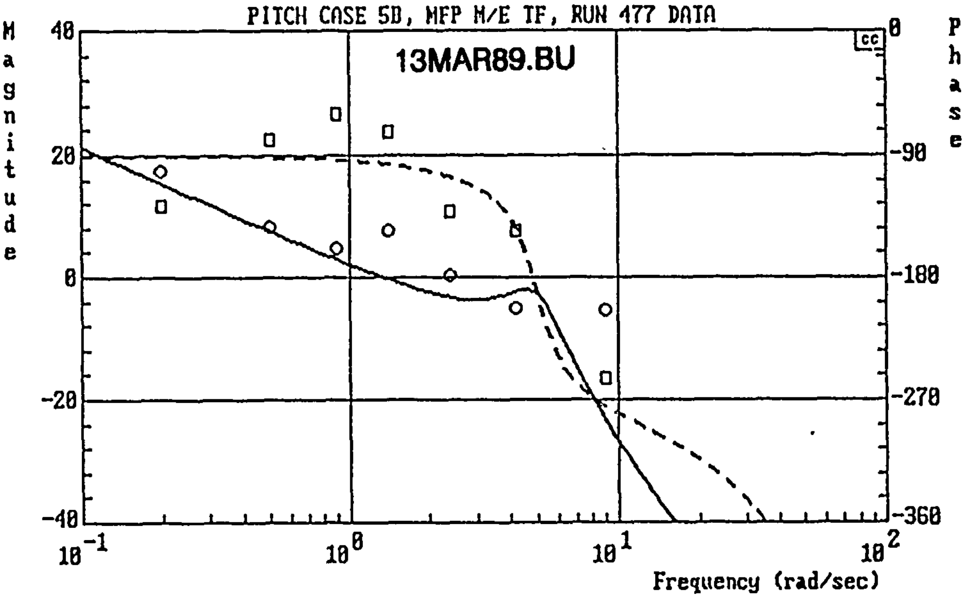


Figure C-6. (Continued)



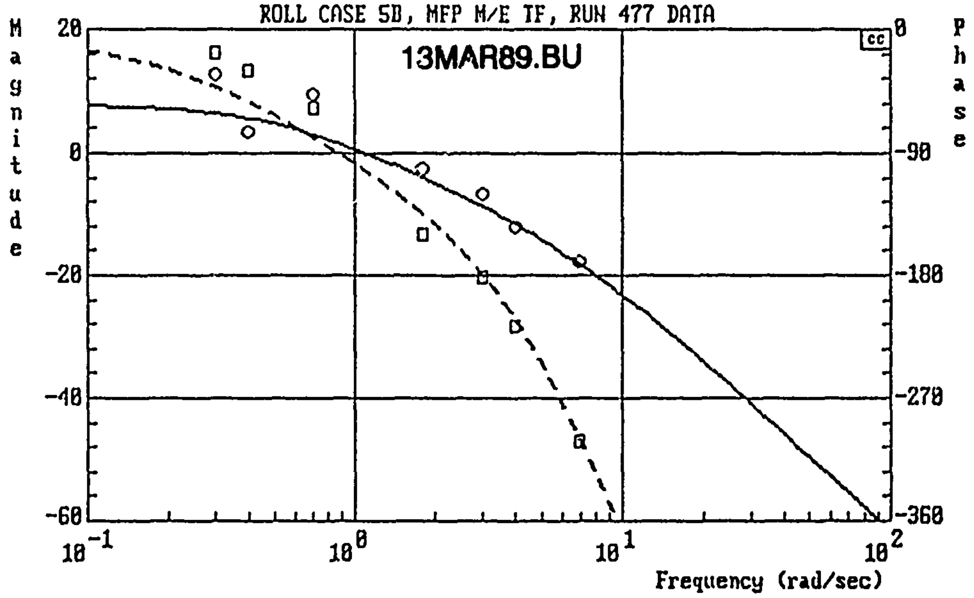
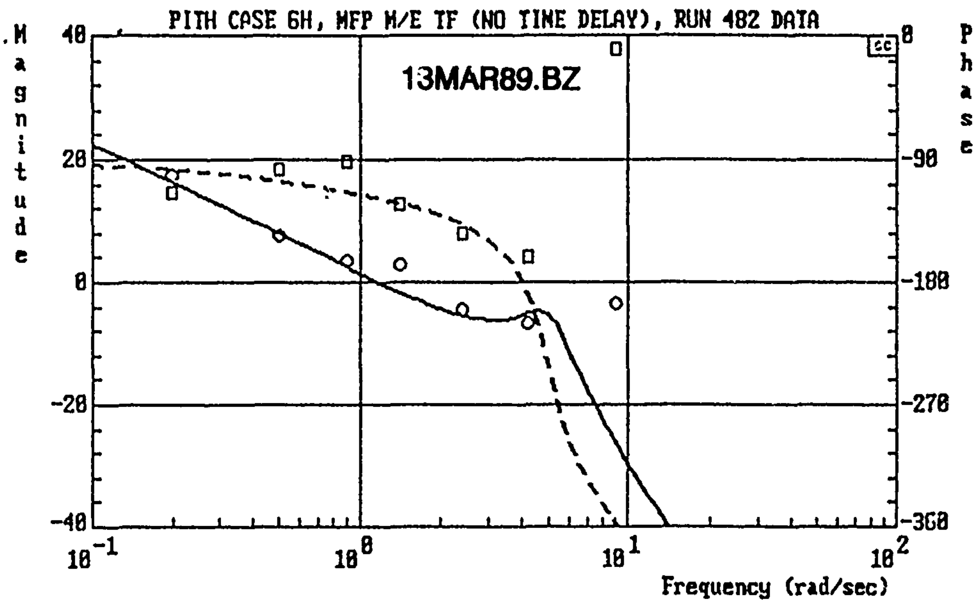


Figure C-6. (Continued)



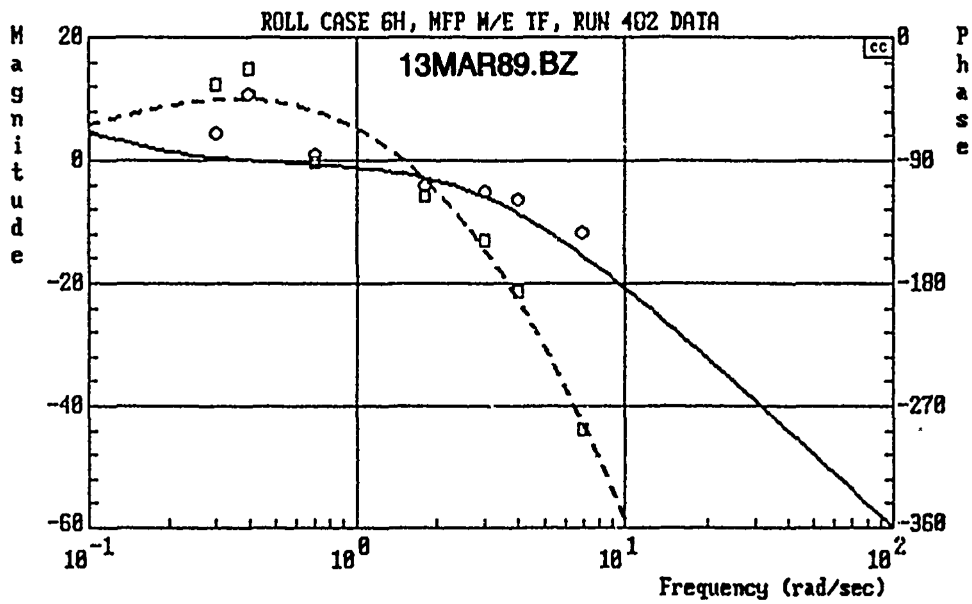
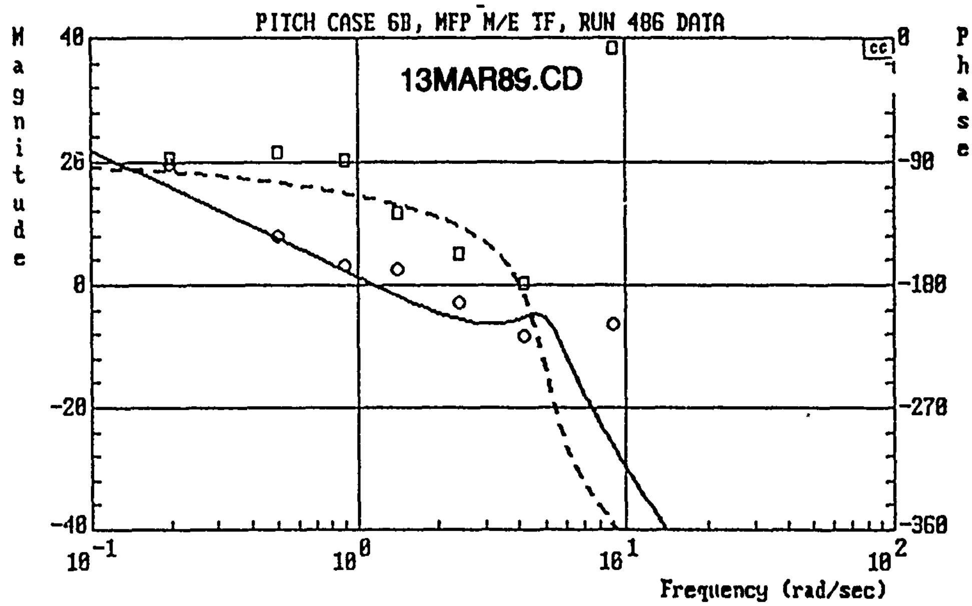


Figure C-6. (Continued)



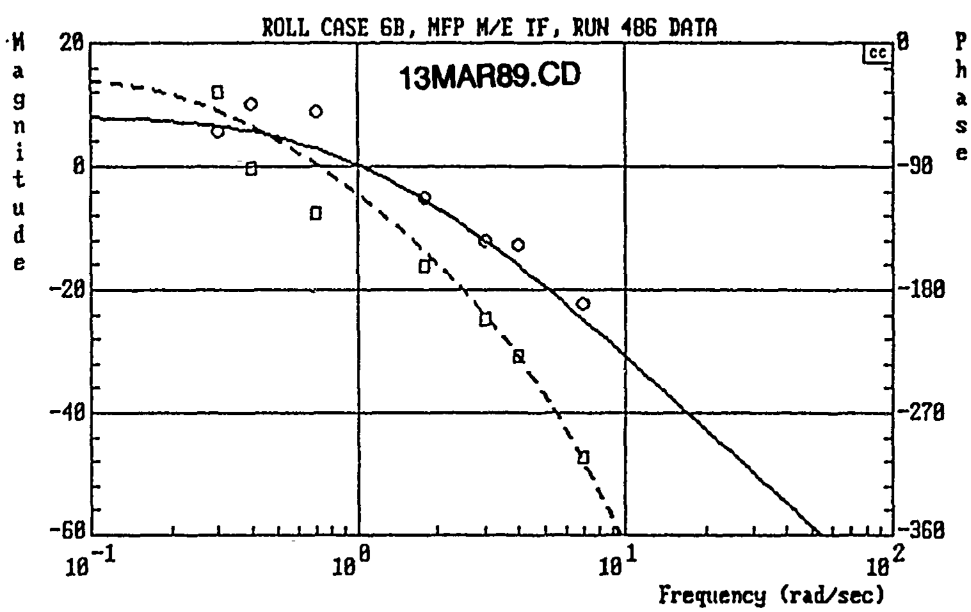
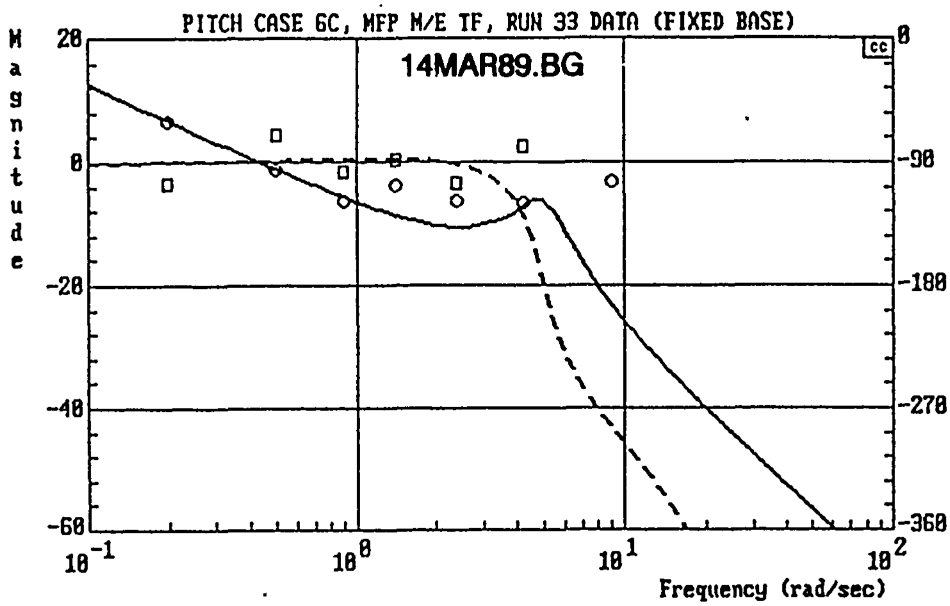


Figure C-6. (Continued)



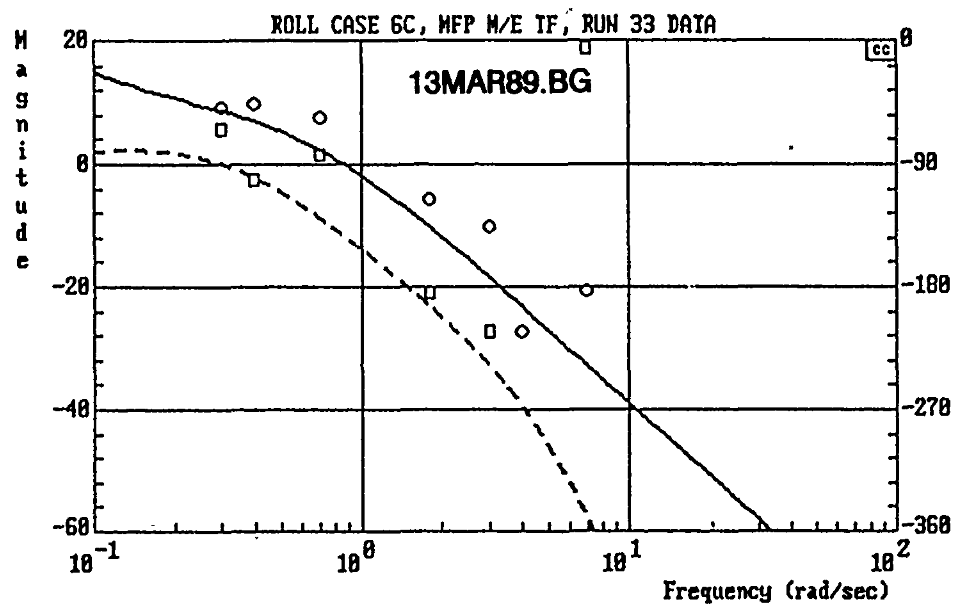
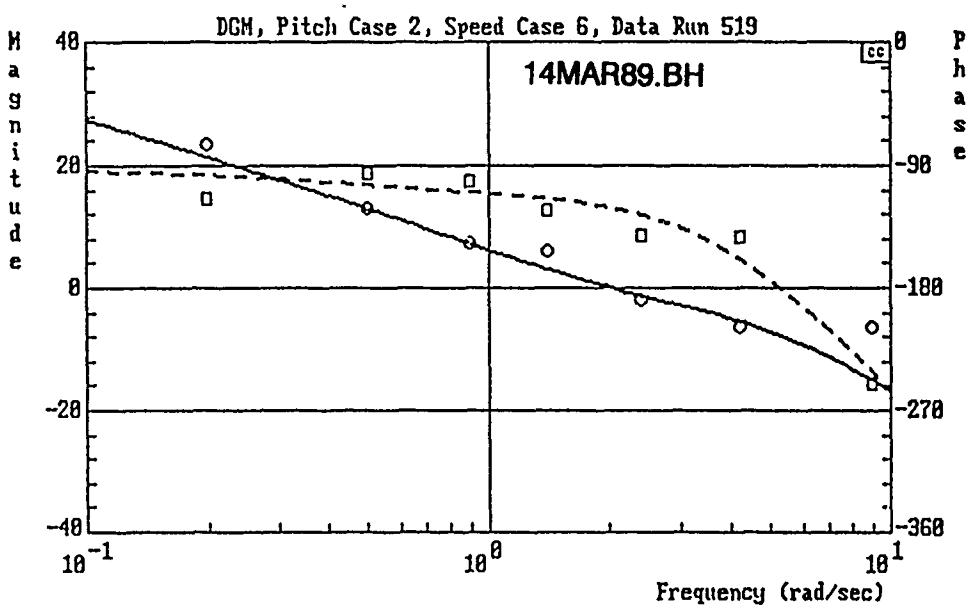


Figure C-6. (Concluded)



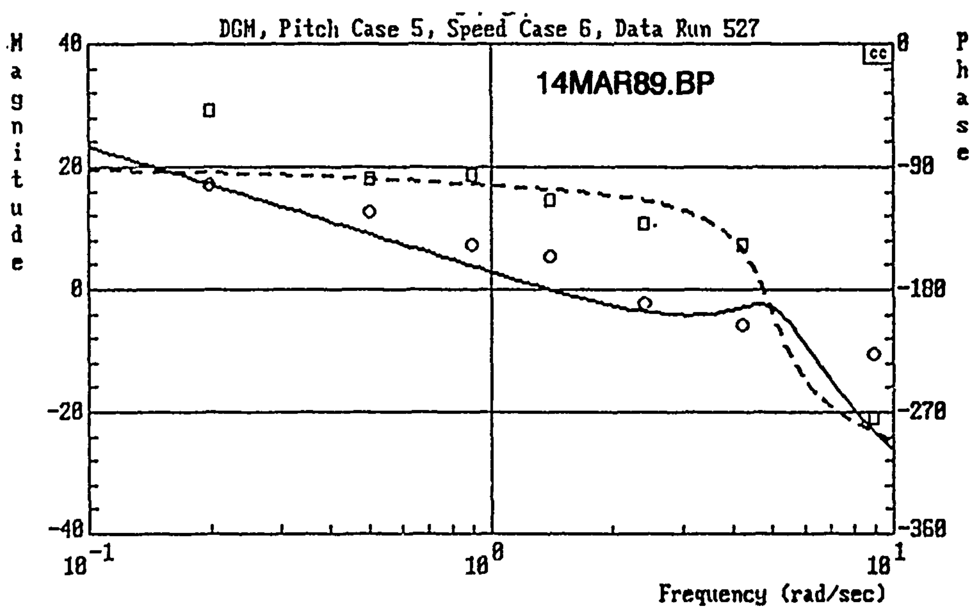
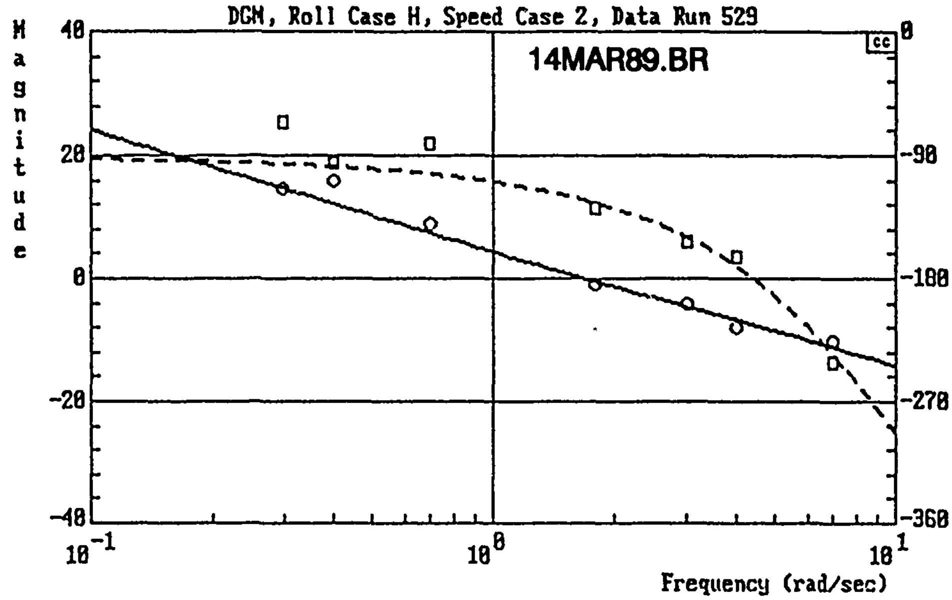


Figure C-7. Y_pY_c Model Versus Data
Pitch/Airspeed - Dual-Axis



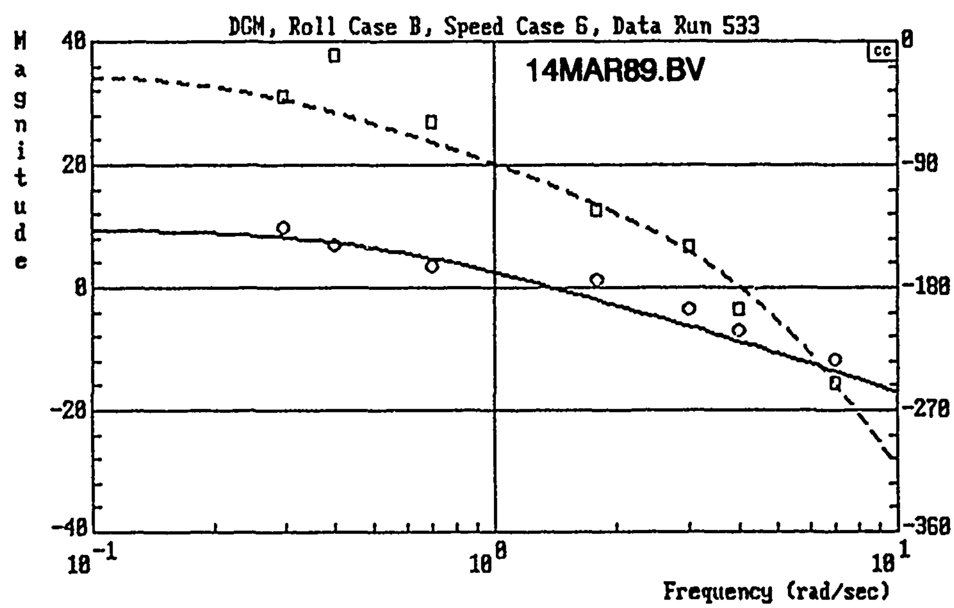
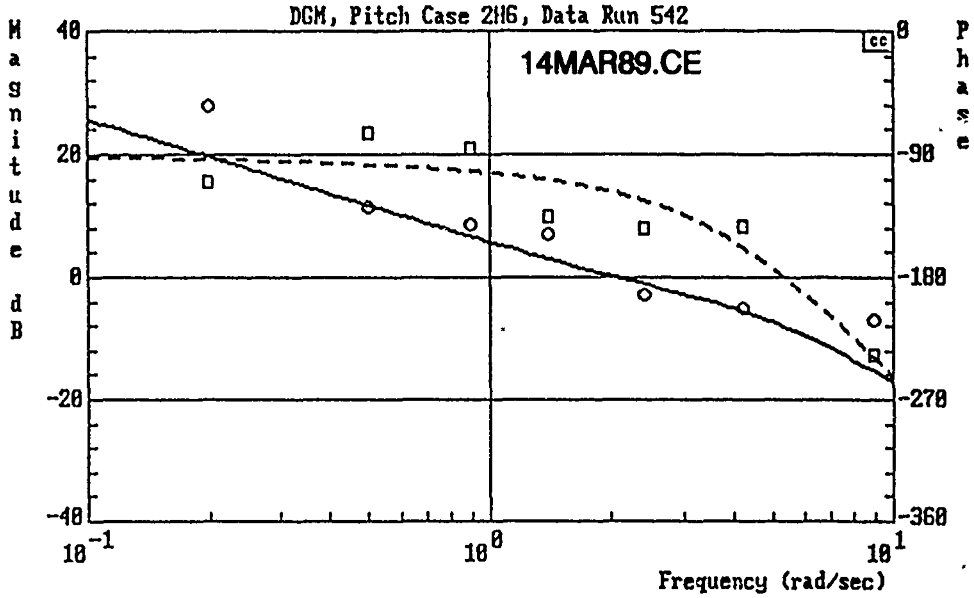


Figure C-8. Y_pY_c Model Versus Data
Roll/Airspeed - Dual-Axis



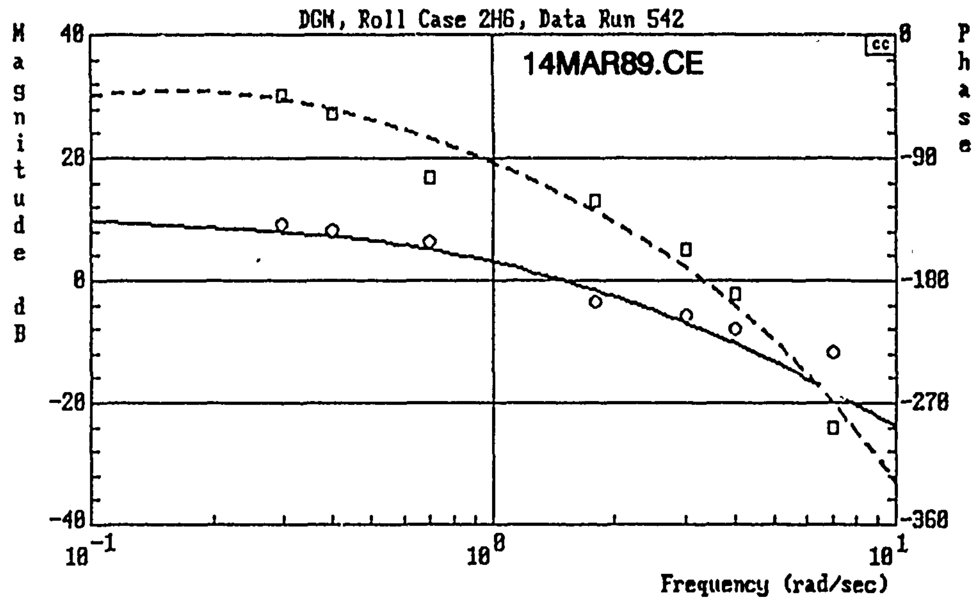
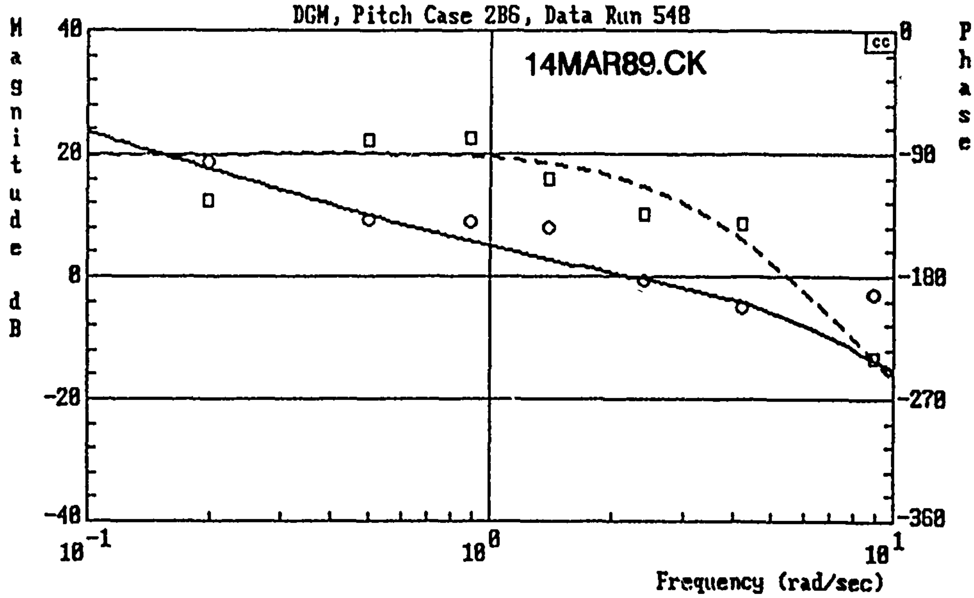


Figure C-9. Y_pY_c Model Versus Data
Three-Axis



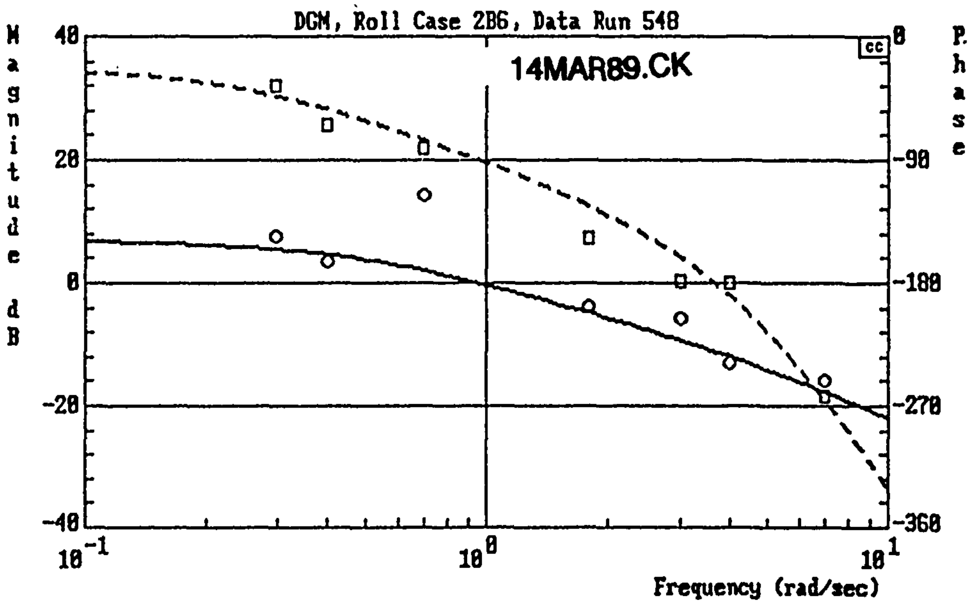
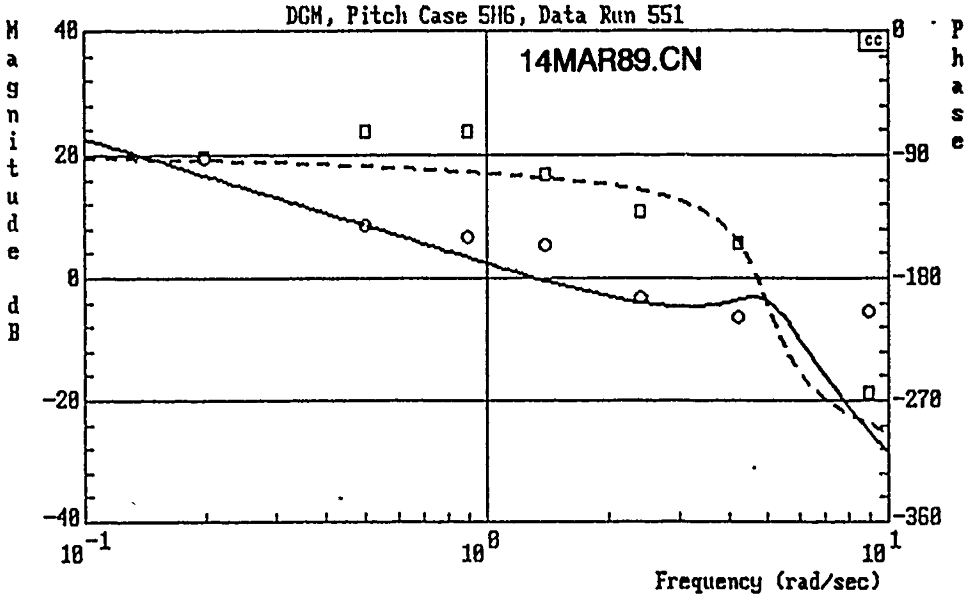


Figure C-9. (Continued)



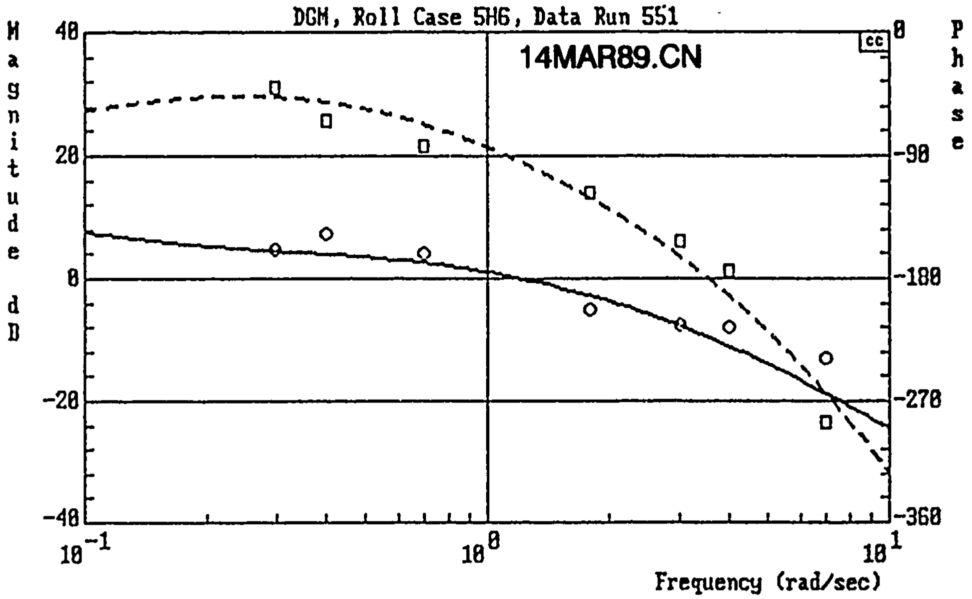


Figure C-9. (Concluded)